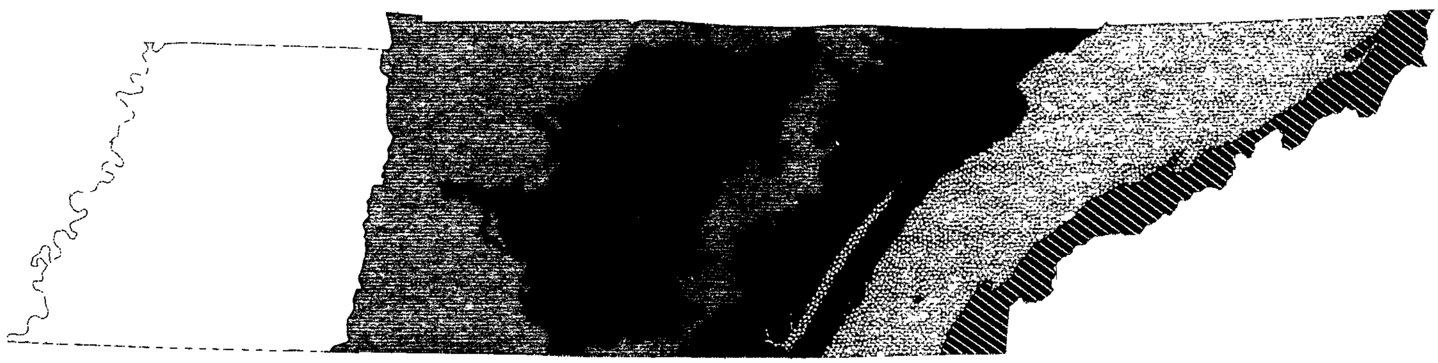
Water-Resources Investigations Report 90-4015

RECHARGE RATES AND AQUIFER HYDRAULIC CHARACTERISTICS FOR SELECTED DRAINAGE BASINS IN MIDDLE AND EAST TENNESSEE



science for a changing world

Prepared by the
U.S. GEOLOGICAL SURVEY

in cooperation with the
TENNESSEE STATE PLANNING OFFICE
and the
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT

RECHARGE RATES AND AQUIFER HYDRAULIC CHARACTERISTICS FOR SELECTED DRAINAGE BASINS IN MIDDLE AND EAST TENNESSEE

By Anne B. Hoos

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 90-4015

Prepared in cooperation with the
TENNESSEE STATE PLANNING OFFICE
and the
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT

Nashville, Tennessee
1990

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
A-413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center, Building 810
Box 25425
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING THE INCH-POUND UNITS TO METRIC UNITS

Multiply inch-pound unit	**by**	**To obtain metric unit**
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
inch per year (in/yr)	2.54	centimeter per year (cm/yr)
mile (mi^2)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

RECHARGE RATES AND AQUIFER HYDRAULIC CHARACTERISTICS FOR SELECTED DRAINAGE BASINS IN MIDDLE AND EAST TENNESSEE

By Anne B. Hoos

ABSTRACT

Quantitative information concerning aquifer hydrologic and hydraulic characteristics is needed to manage the development of ground-water resources. These characteristics are poorly defined for the bedrock aquifers in Middle and East Tennessee where demand for water is increasing. This report presents estimates of recharge rate, storage coefficient, diffusivity, and transmissivity for representative drainage basins in Middle and East Tennessee, as determined from analyses of stream-aquifer interactions. The drainage basins have been grouped according to the underlying major aquifer, then statistical descriptions applied to each group, in order to define areal distribution of these characteristics.

Aquifer recharge rates are estimated for representative "low," "average," and "high" flow years for 63 drainage basins using hydrograph analysis techniques. Net annual recharge during average flow years for all basins ranges from 4.1 to 16.8 in/yr (inches per year), with a mean value of 7.3 in/yr. In general, recharge rates are highest for basins underlain by the Blue Ridge aquifer (mean value 11.7 in/yr) and lowest for basins underlain by the Central Basin aquifer (mean value 5.6 in/yr). Mean recharge values for the Cumberland Plateau, Highland Rim, and Valley and Ridge aquifers are 6.5, 7.4, and 6.6 in/yr, respectively.

Gravity drainage characterizes ground-water flow in most surficial bedrock aquifers in Tennessee. Accordingly, a gravity yield analysis, which compares concurrent water-level and streamflow hydrographs, was used to estimate aquifer storage coefficient for nine study basins. The basin estimates range from 0.002 to 0.140; however, most estimates are within a narrow range of values, from 0.01 to 0.025. Accordingly, storage coefficient is estimated to be 0.01 for all aquifers in Middle and East Tennessee, with the exception of the aquifer in the inner part of the Central Basin, for which storage coefficient is estimated to be 0.002.

Estimates of aquifer hydraulic diffusivity are derived from estimates of the streamflow recession index and drainage density for 75 drainage basins; values range from 3,300 to 130,000 ft^2/d (feet squared per day). Basin-specific and site-specific estimates of transmissivity are computed from

estimates of hydraulic diffusivity and specific-capacity test data, respectively. Basin-specific, or areal, estimates of transmissivity range from 22 to 1,300 ft^2/d, with a mean of 240 ft^2/d. In general, areal transmissivity is highest for basins underlain by the Cumberland Plateau aquifer (mean value 480 ft^2/d) and lowest for basins underlain by the Central Basin aquifer (mean value 79 ft^2/d). Mean transmissivity values for the Highland Rim, Valley and Ridge, and Blue Ridge aquifers are 320, 140, and 120 ft^2/d, respectively. Site-specific estimates of transmissivity, computed from specific-capacity data from 118 test wells in Middle and East Tennessee range from 2 to 93,000 ft^2/d, with a mean of 2,600 ft^2/d. Mean transmissivity values for the Cumberland Plateau, Highland Rim, Central Basin, Valley and Ridge, and Blue Ridge aquifers are 2,800, 1,200, 7,800, 390, and 650 ft^2/d, respectively.

INTRODUCTION

Growth of population and industry in Tennessee has resulted in an increased demand for water. Ground water has commonly been ignored as a potential water-supply source because of the uncertainty of obtaining adequate yields from many of Tennessee's aquifers. This situation is particularly evident in Middle and East Tennessee, where recharge and flow systems in the carbonate, sandstone, and crystalline rock aquifers are poorly understood. Local ground-water availability studies that have been conducted in several parts of these regions have shown a great range of aquifer properties. Large parts of these regions have not been included in any of the local studies.

Most communities in Middle and East Tennessee rely on streams for their water supply. Optimal development and management of water resources in these areas may require conjunctive use of surface water and ground water, especially during periods of low stream flow. Additional knowledge of the hydrologic and hydraulic characteristics of the State's aquifers is essential for wise development of the ground-water resources. For example, a process that can benefit from additional knowledge of aquifer properties is the planning and management of suburban development. In order to determine the maximum population density that can be supplied water by a well or group of wells, the planner needs to estimate the yield that each well can provide without drawing from storage. This yield is approximately equal to the recharge that can be captured in the source area supplying water to a pumped well, so that knowledge of the recharge rate and of the aquifer hydraulic characteristics that influence the size and shape of the source area will permit estimation of yield.

In response to the expected increase in ground-water use, the U.S. Geological Survey, in cooperation with the Tennessee State Planning Office and the Tennessee Department of Health and Environment, began a study in 1985 to assess recharge and aquifer hydraulic characteristics of shallow, unconfined aquifers in the eastern three-quarters of the State (fig. 1). As part of this study, aquifer properties have been estimated for selected drainage basins and well sites using streamflow and specific-capacity test data. The study area is subdivided into five broadly defined physiographic provinces, with differing characteristics. These areas, which have been delineated and described in previous investigations, are shown in figure 2. Mean and median values of the aquifer properties are calculated and compared for these physiographic provinces, which correspond to five major aquifer units.

Purpose and Scope

The purpose of this investigation is to assess recharge and aquifer hydraulic characteristics of shallow, unconfined aquifers in Middle and East Tennessee. This report presents the results of the investigation and describes the methods used to estimate recharge and aquifer

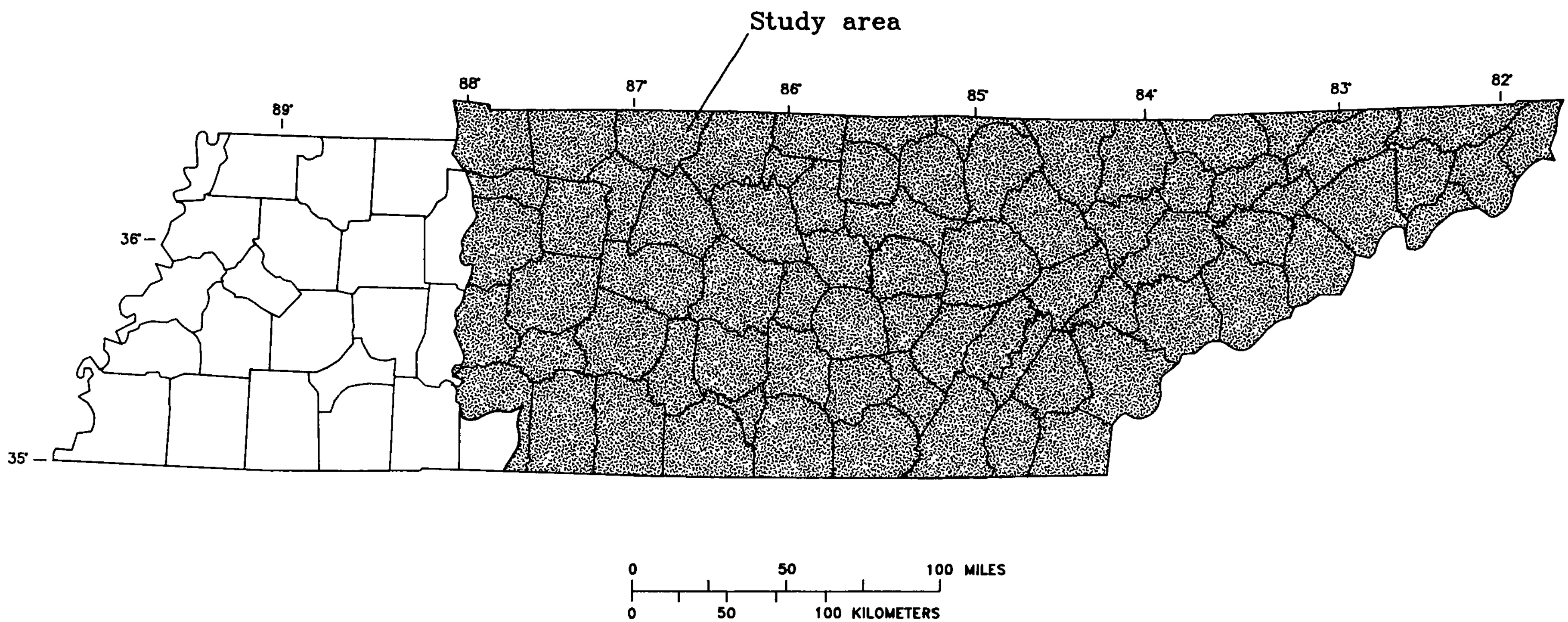
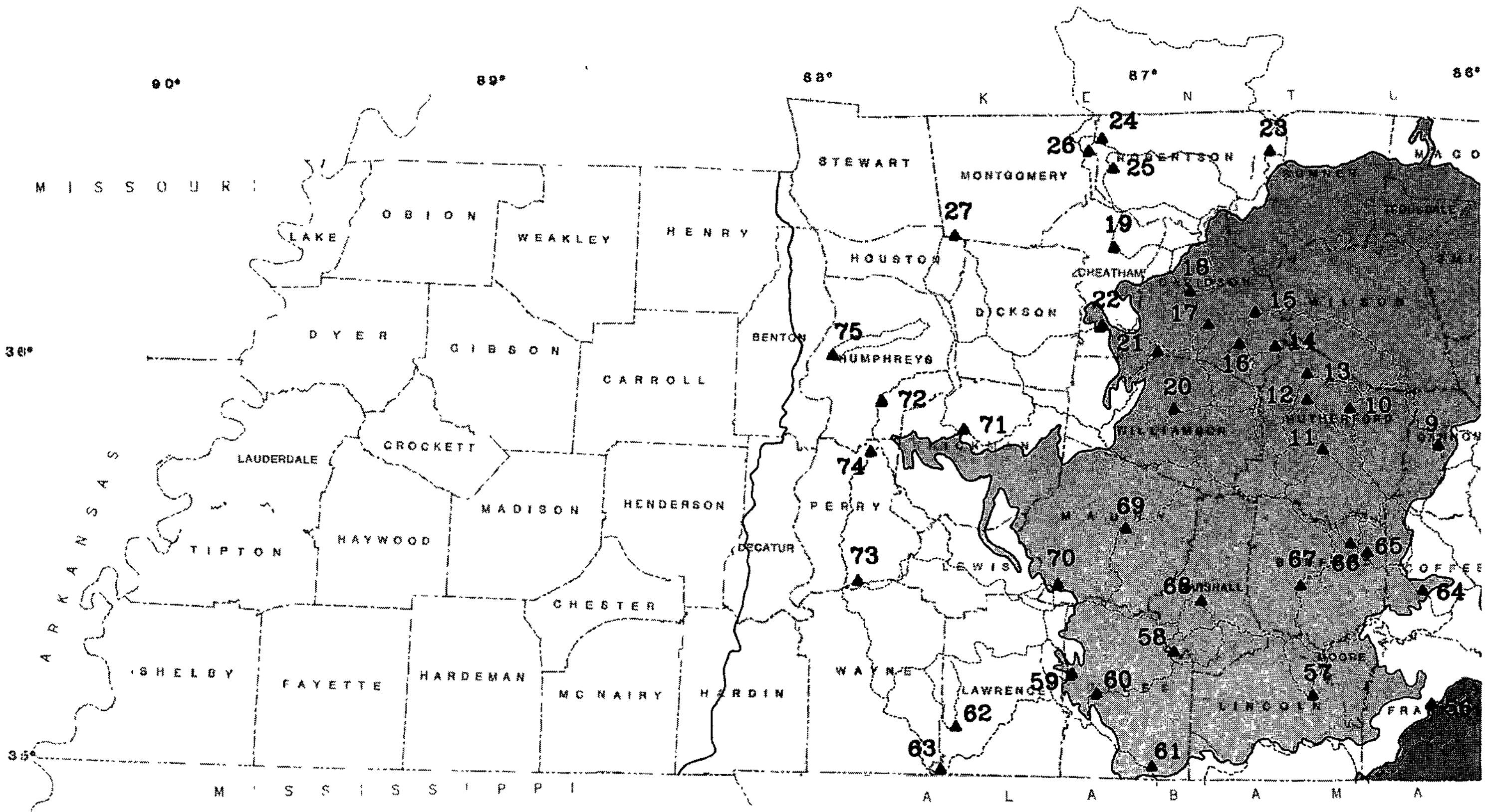
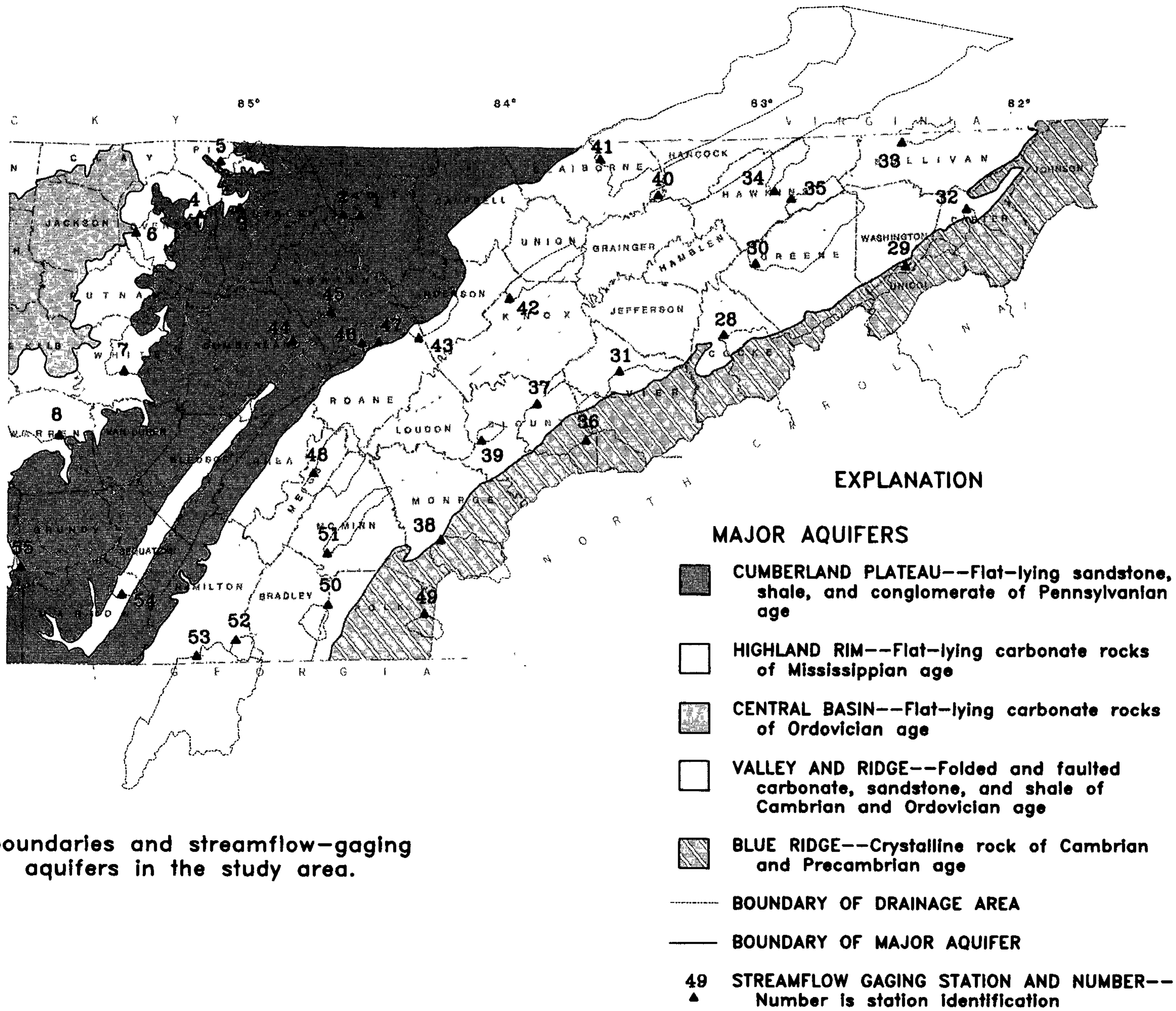


Figure 1.--Location of the study area in Tennessee.



Base from U.S. Geological Survey, State base map, 1:1,000,000, 1957, revised 1973

Figure 2.--Location of drainage area stations for study basins and major



boundaries and streamflow-gaging
aquifers in the study area.

hydraulic characteristics for selected drainage basins. The assessment of aquifer properties for such a large area (approximately 30,000 mi^2) requires evaluation on a regional scale. A large part of the data for this evaluation has been derived from base-flow analysis, a valuable tool for determining regional values and variability of aquifer properties. All of the methods used are based on assumption of ideal conditions in the aquifer; for example, homogeneous and isotropic materials. Because conditions in the aquifers are not ideal throughout the area, the estimates may not accurately or precisely quantify the aquifer properties in all areas.

Estimates are presented for values of net annual recharge rate, transmissivity based on hydrograph analysis, and storage coefficient for the basins. In addition, values for transmissivity estimated from specific-capacity tests are listed. Statistical descriptions of these estimates, organized by major aquifer unit, are given to define the areal distribution of these characteristics.

Acknowledgment

The author gratefully acknowledges the assistance of Guiford Miller of Lawrenceburg, Tenn., who provided specific-capacity data and shared information gained through many years of experience in drilling and developing wells throughout Middle and East Tennessee.

GEOHYDROLOGIC CHARACTERISTICS OF MAJOR AQUIFERS

The five major aquifers within the study area (fig. 2) correspond to five physiographic provinces. Most of the following discussion of the geohydrology of each aquifer is taken from Zurawski (1978) and Bradley and Hollyday (1985); the summary of topography is taken from Miller (1974).

The Cumberland Plateau aquifer (formerly known as the Pennsylvanian sandstone aquifer) consists of generally flat-lying sandstone, shale, and conglomerate of Pennsylvanian age and underlies the Cumberland Plateau physiographic province (fig. 2). Land surface in this province is gently rolling to hilly, bordered by a prominent escarpment on both sides. Altitude of the plateau surface is generally between 1,700 and 1,900 feet above sea level; the height of the escarpments averages 900 feet. Regolith is generally less than 4 feet thick. Water is stored in and moves through fractures, faults, and bedding plane openings in the bedrock. Wells commonly yield from 5 to 50 gal/min.

The Highland Rim aquifer (formerly known as the Mississippian carbonate aquifer) consists of flat-lying carbonate rocks of Mississippian age and underlies the Highland Rim physiographic province (fig. 2). Land in the eastern, northern, and southern parts of the province is predominantly undulating, whereas the western part is more dissected and hilly to steep. Altitude of land surface averages about 1,000 feet above sea level. The bedrock formations weather to form a deep (up to 100 feet thick) chert regolith, which stores ground water and releases it to openings in the bedrock. Fractures in the bedrock have been widened selectively by solution, permitting rapid transmission of water, as well as providing some storage. Well yields commonly range from 5 to 50 gal/min.

The Central Basin aquifer (formerly known as the Ordovician carbonate aquifer) consists of generally flat-lying carbonate rocks of Ordovician age and underlies the Central Basin physiographic province (fig. 2). The outer part of the Central Basin is predominantly hilly and steep; average altitude of land surface is about 750 feet above sea level. Regolith in the outer part of the Central Basin ranges from less than 2 to more than 10 feet thick. Land in the inner part of the province is predominantly rolling and undulating, with an average altitude of about 600 feet above sea level. Regolith cover in the inner part of the province is thin (less than a foot) to absent (Springer and Elder, 1980). Water is stored in and moves through solution-enlarged vertical joints and horizontal bedding planes. Wells commonly yield from 5 to 20 gal/min.

The Valley and Ridge aquifer (formerly known as the Cambrian-Ordovician carbonate aquifer) consists of extensively folded and faulted carbonate, sandstone, and shale of Cambrian and Ordovician age underlying the Valley and Ridge physiographic province. The rock formations crop out alternately in long, narrow belts, so that aquifer characteristics show marked areal variability. The ridges range in altitude from about 1,500 to over 3,000 feet above sea level; valleys generally range between 750 and 1,000 feet above sea level. Generally regolith is thin over the shales and sandstones and thick over the limestone. The sandstone and shale units are poor aquifers; nearly all the high-producing wells and springs are in the dolomitic limestone formations. Water moves through solution-enlarged fractures, which in areas may form extensive networks. The folding and faulting has produced regional anisotropy in aquifer hydraulic properties, and ground water may move preferentially in strike-parallel or strike-normal directions. Well yields commonly range from 5 to 200 gal/min.

The Blue Ridge aquifer (formerly known as the crystalline rock aquifer) consists of crystalline rock of Cambrian and Precambrian age underlying the Blue Ridge physiographic province. The province is characterized by extremely rugged terrain, with several mountain peaks higher than 6,000 feet above sea level, and valleys ranging from 1,000 to 1,500 feet above sea level. The aquifer consists of dense, fractured bedrock covered on the lower parts of the slopes with a thick mantle (as much as 100 feet) of regolith, alluvium, and colluvium. The regolith stores ground water, releasing it to fractures in the bedrock. The essentially unmodified fracture openings contribute very little to storage, functioning mainly to transmit water stored in the regolith. Wells yield from 5 to 50 gal/min.

SELECTION AND CLASSIFICATION OF DRAINAGE BASINS

Seventy-five drainage basins were selected to provide a representative sample of climatic, geographic, and geohydrologic conditions in Middle and East Tennessee. The drainage area boundary and streamflow-gaging station for each of the selected drainage basins, referred to in this report as study basins, are shown in figure 2. These 75 sites represent all the continuous-record gaging stations studied by Bingham (1986, p. 18) that are within the study area. These sites had continuous-streamflow record of sufficient length to define the low-flow characteristics of the stream, and streamflows were not appreciably affected by man's activities in the basin.

The drainage area boundary for each of the study basins was delineated using 1:250,000 scale topographic maps. Each study basin was classified according to the aquifer underlying the major part (more than 75 percent) of the drainage area. Study basins in which no single major aquifer unit underlies more than 75 percent of the drainage area were not classified for regional analysis.

RECHARGE RATES

Procedure

Although recharge to an aquifer cannot be measured directly, it can be estimated from its relation to other components of the hydrologic budget. The annual hydrologic budget for an aquifer can be expressed as:

$$\Delta S = R - Ds - Dw - Da - De, \qquad (1)$$

where

ΔS is the annual change in storage of the aquifer;

R is annual recharge from precipitation, losing streams, and adjacent aquifers;

Ds is annual discharge from the aquifer to streams;

Dw is annual discharge from the aquifer to wells;

Da is annual discharge from the aquifer to underlying aquifers; and

De is annual discharge from the aquifer to evapotranspiration.

Each of the components may be expressed as a volume flux per surface area of the aquifer (inches per year). Throughout most of the study area, water levels exhibit only seasonal fluctuations. Therefore, on an annual basis, steady-state conditions predominate ($\Delta S = 0$) and discharge approximately equals recharge. Furthermore, ground-water use is negligible ($Dw = 0$) and leakage to underlying aquifers is assumed to be insignificant ($Da = 0$). Accordingly, equation (1) reduces to

$$R = Ds + De. \tag{2}$$

Aquifer discharge to streams (Ds), commonly known as base flow, can therefore be used to approximate net recharge (Rnet), where net recharge is defined as total recharge minus ground-water evapotranspiration:

$$Rnet = R - De = Ds. \tag{3}$$

Because recharge rates vary considerably from year to year, these rates have been determined for representative "low", "average", and "high" flow years for each study basin. For this study it was assumed that a continuous-streamflow record of 10 years or more contains flow years representative of each of these hydrologic conditions.

Base flow was separated by analysis of streamflow hydrographs using a method developed by Rorabaugh (1964) and Daniel (1976). A detailed description of the Rorabaugh-Daniel method as it was applied in this analysis is given by Bevans (1986, p. 57-64). This method assumes uniform, homogeneous, and isotropic conditions within the aquifer, equal distances from stream to ground-water divides throughout the basin, and water levels everywhere horizontal and equal to stream level prior to recharge events. Because these conditions do not exist in the aquifers studied, it is recognized that the method does not permit completely accurate or precise quantification of recharge rates.

Application of the method requires an estimate of the slope of the base-flow recession curve, also known as the streamflow recession index, for the basin. Estimates of the streamflow recession index for each of the 75 study basins were obtained from Bingham (1986). To account for the effects of ground-water evapotranspiration losses on base flow, a dimensionless family of type curves describing ground-water discharge from an aquifer with constant evapotranspiration has been developed by Rorabaugh (Daniel, 1976, p. 361). The observed base-flow recession curve following a recharge event is compared to the family of curves to determine the volume of recharge from the event and the rate of ground-water evapotranspiration.

Hydrograph analysis to evaluate ground-water recharge is illustrated with an example analysis for the gaging station Lick Creek at Mohawk (station number 03467000, station identification number 30 on figure 2). The drainage basin for this station covers approximately 220 mi^2 and is underlain by the Valley and Ridge aquifer (fig. 2). The annual mean streamflow for the 25 water years of streamflow record (1947-71) is shown in figure 3. The water years 1948, 1950, and 1965 were selected to

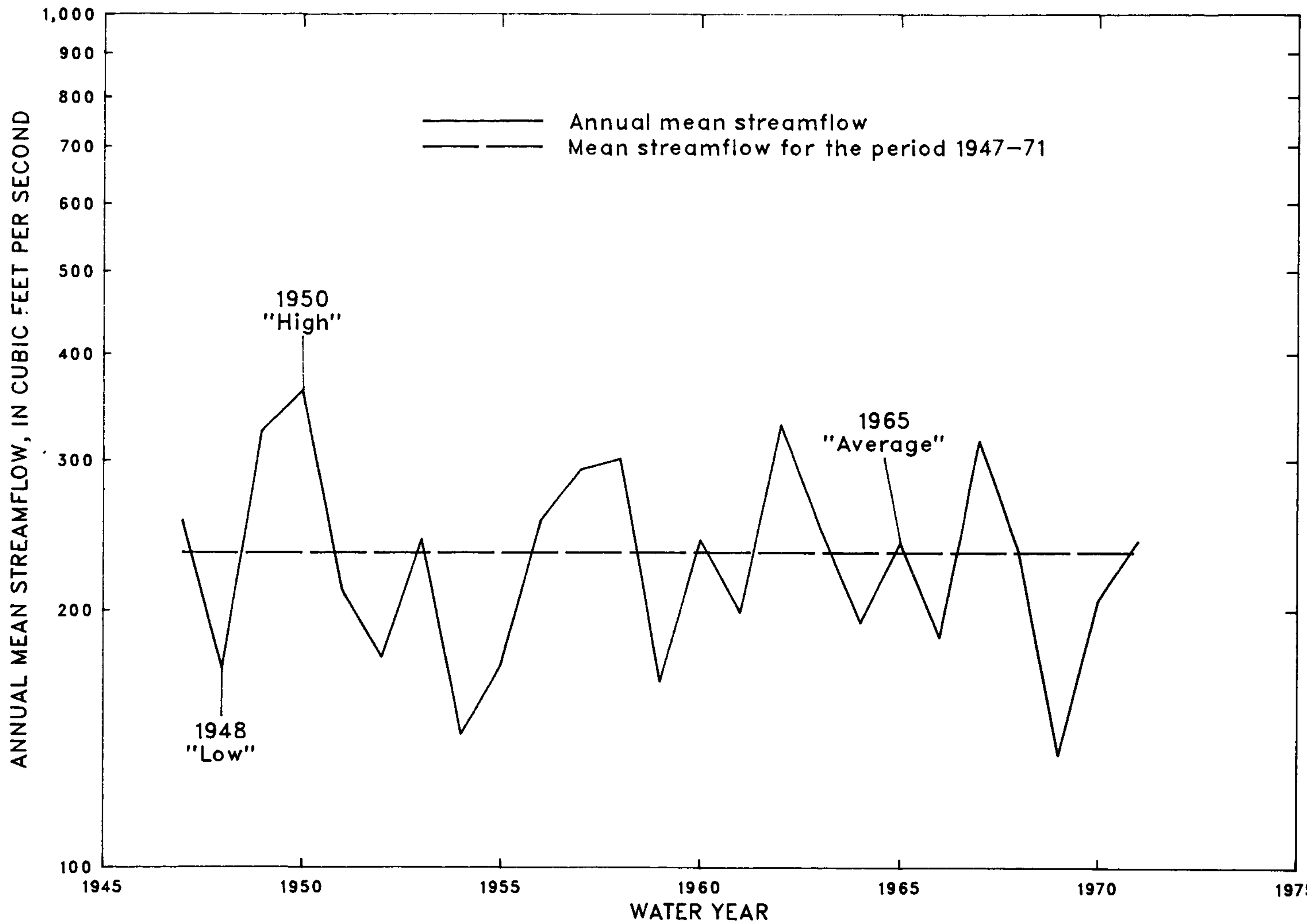


Figure 3.—–Annual mean streamflow for Lick Creek at Mohawk, Tenn. (03467000), with selected representative "high", "average" and "low" flow years (Station location is shown as identification number 30 on figure 2).

represent "low," "high," and "average" flow conditions, respectively. Although lowest annual mean streamflow for the period of record occurred during 1969, the hydrograph for that water year was judged to be unsuitable for the analysis because the rapid succession of runoff events during the summer period precluded observation of the base-flow recession curve following each event.

The example hydrograph analysis for water year 1950 is shown graphically in figure 4. The hydrograph was divided into two distinct periods. During the major streamflow rise period, from mid-October to early-April, streamflow increased and then remained at a relatively high level. A constant aquifer recharge rate of 5.81 inches was calculated for this period (table 1). The major streamflow recession period, which began in early-April and lasted through September, was characterized by intervals of recession interrupted by episodes of high streamflow. Net recharge during the major streamflow recession period was computed as 1.77 inches by summing a series of impulse recharge events (1.81 inches) and subtracting evapotranspiration (0.04 inches). Net annual recharge for the year, then, is 7.58 inches (table 1).

Results

Estimates of recharge rates based on hydrograph analysis for 10 of the study basins are presented in table 1. Statistical analysis of these estimates revealed a strong positive correlation ($r = 0.97$) between recharge during the major rise period (Rmr) and net annual recharge (Rnet) (fig. 5). Faye and Mayer (1989) have suggested that the strong correlation between these variables can be used in an estimation procedure for net annual recharge. Accordingly, a regression relation between the two variables was developed using a least squares analysis. The regression equation is

$$\mathrm{Rnet} = 1.33 * \mathrm{Rmr}^{0.93} \qquad (4)$$

with a standard error of the estimate of 10 percent. This equation and the estimate of recharge during the major rise period were used to calculate net annual recharge rates for the remaining study basins during "high," "average," and "low" flow years (table 2). Values for the "average" flow year for all basins range from 4.1 to 16.8 in/yr, with a mean value of 7.3 in/yr and median value of 6.5 in/yr. In general, recharge rate is lowest for basins underlain by the Central Basin and Cumberland Plateau aquifers and highest for basins underlain by the Blue Ridge aquifer. Statistical summaries of the estimates, organized by major aquifer, are shown in table 3. Statistical summaries of the entire data set, which includes some basins not assigned to a single major aquifer, are also given (table 3). A one-way analysis of variance test was conducted on the estimates from each major aquifer. At the 95 percent confidence level, the recharge rate for basins underlain by the Central Basin aquifer is significantly lower (mean value 5.6 in/yr) than for the other basins. Using the same procedure, the recharge rate for basins underlain by the Blue Ridge aquifer is significantly higher (mean value 11.7 in/yr) than for other basins. The other three groups of estimates, for the Cumberland Plateau, Highland Rim, and Valley and Ridge aquifers, were found not to be statistically different from each other, with mean values of 6.5, 7.4, and 6.6 in/yr, respectively.

Most of the basins underlain by the Valley and Ridge aquifer are partly underlain by tight sandstone and shale units, in addition to high-yielding carbonate rocks. The belief that the estimates would be higher if drainage basins underlain only by the carbonate rocks were considered is supported by the estimate for the only such basin in this group, Oostanaula Creek near Sanford (station number 03565500, station identification number 51 on figure 2), which has an estimated recharge rate of 8.2 in/yr.

Table 1.--*Net annual recharge rates estimated by hydrograph analysis*

[CP = Cumberland Plateau aquifer; HR = Highland Rim aquifer; CB = Central Basin aquifer; VR = Valley and Ridge aquifer; BR = Blue Ridge aquifer]

Station identification number (fig. 2)	Major aquifers	Station number	Station name	Water year	Flow condition	Recharge during major rise period, in inches	Net annual recharge, in inches
9	HR	03426800	E FK STONES R AT WOODBURY, TENN.	1975	High	12.1	13.7
9	HR	03426800	E FK STONES R AT WOODBURY, TENN.	1971	Average	7.7	8.9
9	HR	03426800	E FK STONES R AT WOODBURY, TENN.	1981	Low	3.0	3.9
10	CB	03427500	E FK STONES R NR LASCASSAS, TENN.	1973	High	8.2	8.9
10	CB	03427500	E FK STONES R NR LASCASSAS, TENN.	1958	Average	3.7	4.1
10	CB	03427500	E FK STONES R NR LASCASSAS, TENN.	1981	Low	1.9	2.3
20	CB	03432350	HARPETH RIVER AT FRANKLIN, TENN.	1979	High	5.8	7.7
20	CB	03432350	HARPETH RIVER AT FRANKLIN, TENN.	1976	Average	5.1	6.0
20	CB	03432350	HARPETH RIVER AT FRANKLIN, TENN.	1985	Low	3.6	3.7
30	VR	03467000	LICK CREEK AT MOHAWK, TENN.	1950	High	5.8	7.6
30	VR	03467000	LICK CREEK AT MOHAWK, TENN.	1965	Average	4.4	5.2
30	VR	03467000	LICK CREEK AT MOHAWK, TENN.	1948	Low	[a]1.8	2.6
32	BR	03485500	DOE RIVER AT ELIZABETHTON, TENN.	1975	High	12.3	16.1
32	BR	03485500	DOE RIVER AT ELIZABETHTON, TENN.	1959	Average	9.4	10.7
32	BR	03485500	DOE RIVER AT ELIZABETHTON, TENN.	1969	Low	8.4	10.1
36	BR	03497300	LITTLE R ABOVE TOWNSEND, TENN.	1974	High	17.3	21.2
36	BR	03497300	LITTLE R ABOVE TOWNSEND, TENN.	1976	Average	[a]10.3	16.8
36	BR	03497300	LITTLE R ABOVE TOWNSEND, TENN.	1970	Low	12.7	14.7
43	VR,CP	03538225	POPLAR CR NEAR OAK RIDGE, TENN.	1973	High	14.2	14.8
43	VR,CP	03538225	POPLAR CR NEAR OAK RIDGE, TENN.	1984	Average	8.8	9.4
43	VR,CP	03538225	POPLAR CR NEAR OAK RIDGE, TENN.	1981	Low	2.2	3.0
46	CP	03540500	EMORY RIVER AT OAKDALE, TENN.	1973	High	10.3	10.2
46	CP	03540500	EMORY RIVER AT OAKDALE, TENN.	1970	Average	8.2	8.9
46	CP	03540500	EMORY RIVER AT OAKDALE, TENN.	1969	Low	3.4	3.7
50	VR	03565300	S CHESTUEE CR NEAR BENTON, TENN.	1973	High	12.8	13.4
50	VR	03565300	S CHESTUEE CR NEAR BENTON, TENN.	1978	Average	5.0	5.6
50	VR	03565300	S CHESTUEE CR NEAR BENTON, TENN.	1970	Low	4.3	5.1
64	HR	03596000	DUCK R BELOW MANCHESTER, TENN.	1974	High	8.0	10.1
64	HR	03596000	DUCK R BELOW MANCHESTER, TENN.	1965	Average	8.5	9.8
64	HR	03596000	DUCK R BELOW MANCHESTER, TENN.	1981	Low	3.3	4.0

[a]Data pair not used in the regression analysis.

AQUIFER HYDRAULIC CHARACTERISTICS

Hydraulic characteristics that determine the potential of an aquifer to be a water-supply source are transmissivity and the storage coefficient. The principal method for estimating these characteristics has been the application of equations developed by Theis (1935, 1963) to data from tests of pumped wells, termed "aquifer tests and specific-capacity tests." Compilation of these estimates for characterization of an aquifer at a regional scale generally has been unsuccessful because of insufficient data, and because aquifer-test and specific-capacity test data are site specific. Methods have been developed to

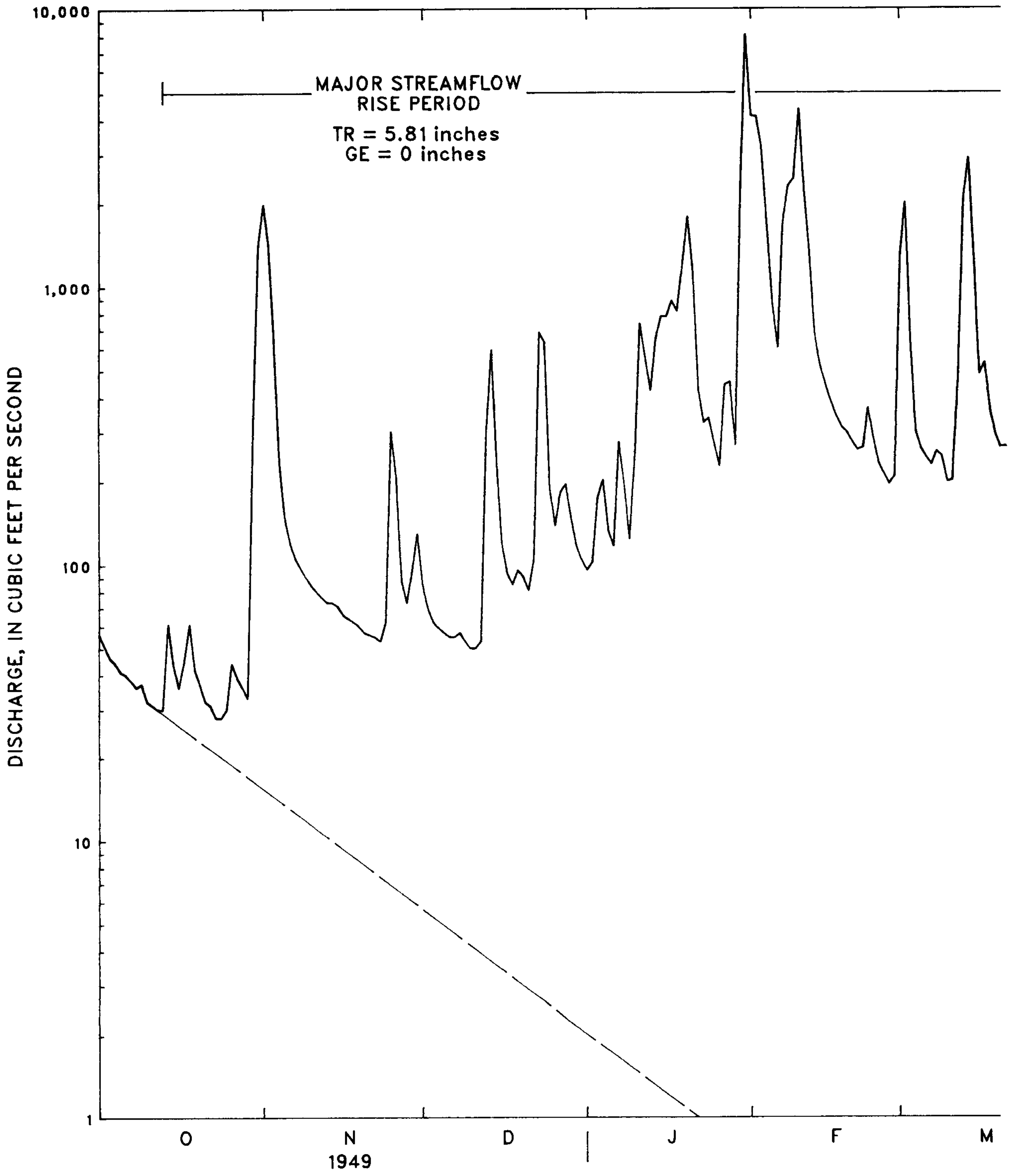
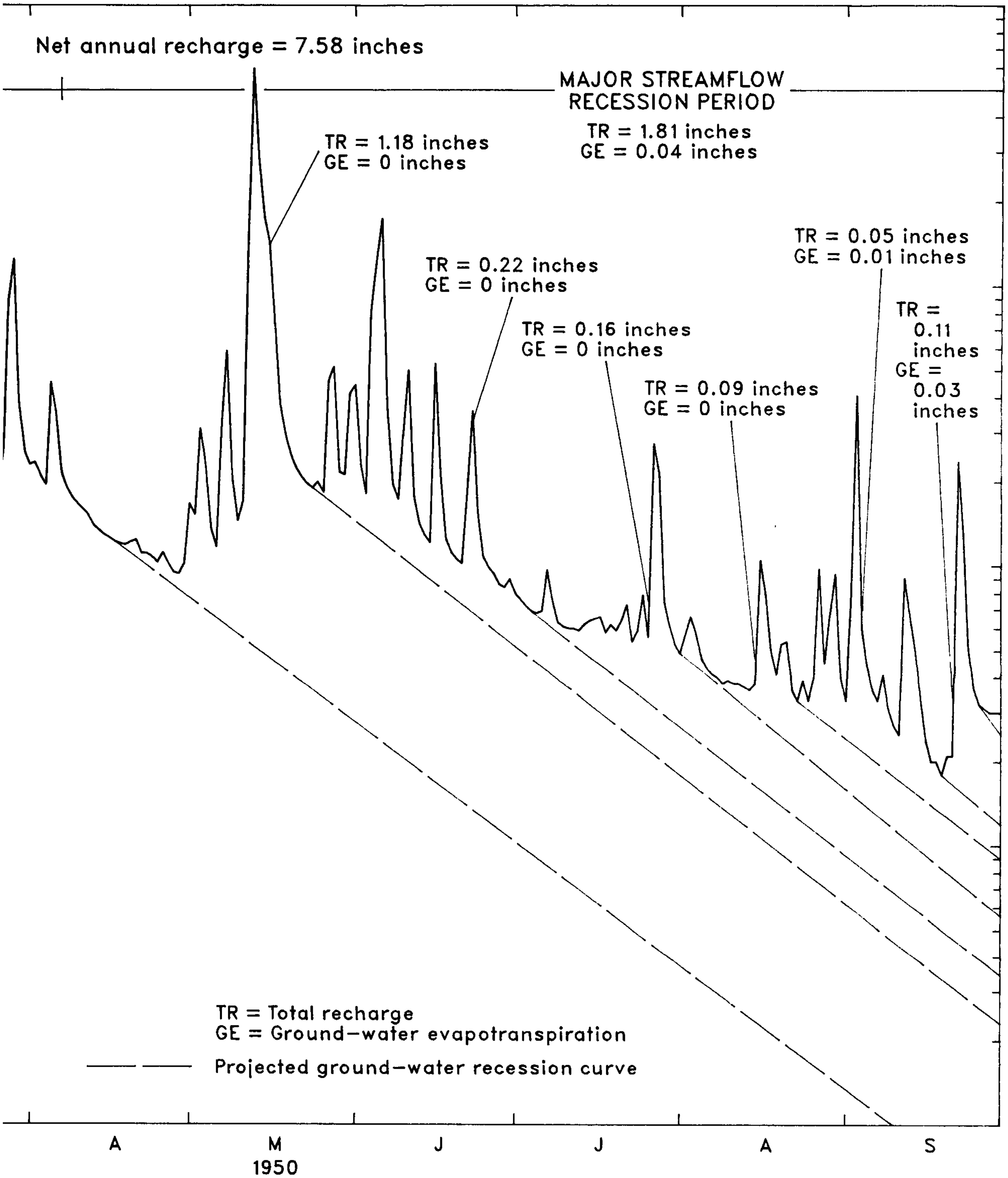


Figure 4.—–Analysis of the streamflow hydrograph o
(Station location is shown as statio



ick Creek at Mohawk, Tenn. (03467000), for water year 1950
dentification number 30 on figure 2).

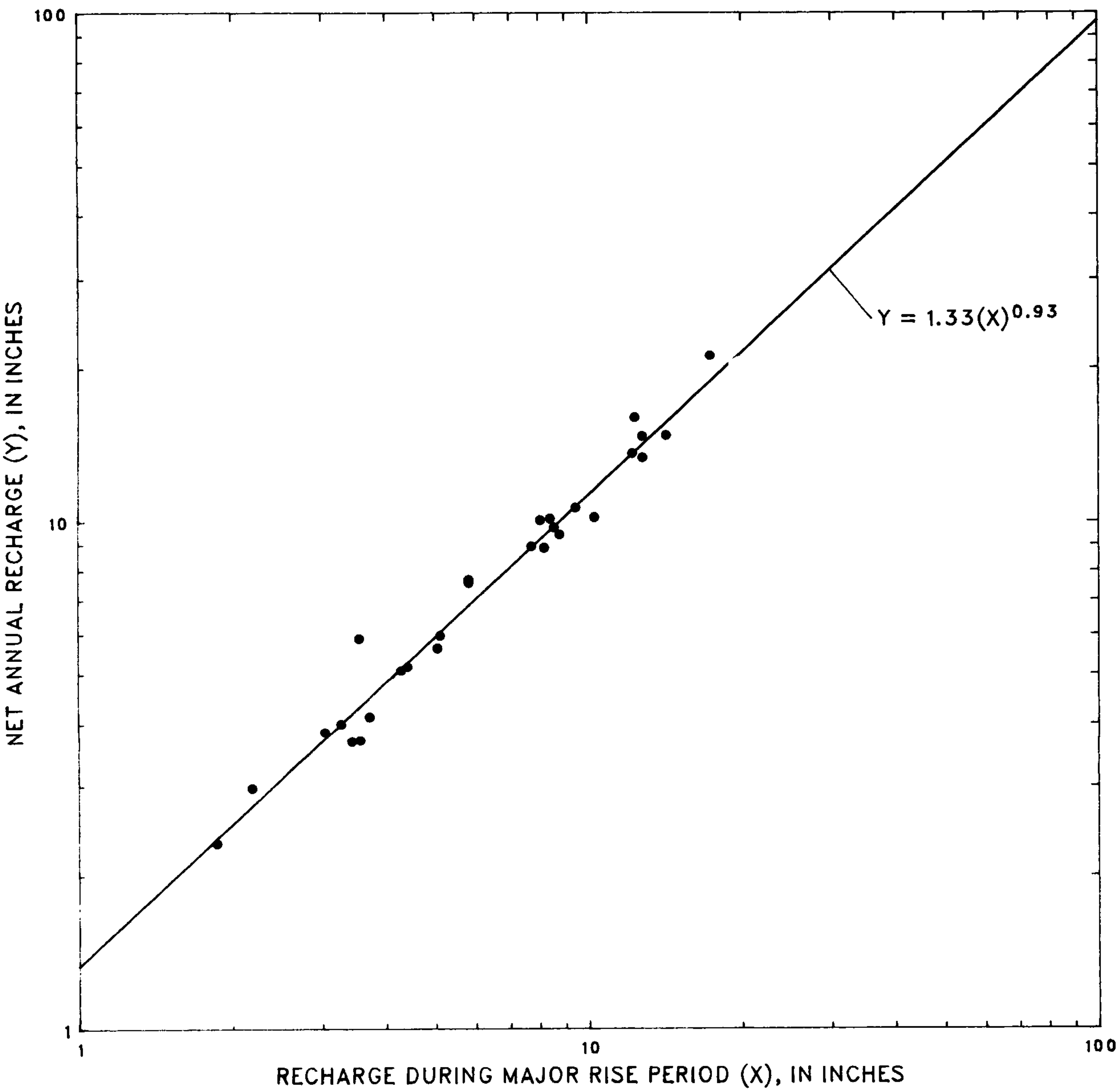


Figure 5.−−Relation between recharge during the major rise period and net annual recharge.

Table 2.--*Net annual recharge rates estimated by hydrograph analysis and regression relation*

[CP = Cumberland Plateau aquifer; HR = Highland Rim aquifer; CB = Central Basin aquifer; VR = Valley and Ridge aquifer; BR = Blue Ridge aquifer]

Station identification number (fig. 2)	Major aquifers	Station number	Station name	Water year	Flow condition	Net annual recharge, in inches
1	CP	03408500	NEW RIVER AT NEW RIVER, TENN.	1972	High	14.0
1	CP	03408500	NEW RIVER AT NEW RIVER, TENN.	1961	Average	5.5
1	CP	03408500	NEW RIVER AT NEW RIVER, TENN.	1981	Low	2.4
2	CP	03409500	CLEAR FORK NEAR ROBBINS, TENN.	1979	High	7.4
2	CP	03409500	CLEAR FORK NEAR ROBBINS, TENN.	1968	Average	4.3
2	CP	03409500	CLEAR FORK NEAR ROBBINS, TENN.	1981	Low	3.5
3	CP	03414500	E FK OBEY R NR JAMESTOWN, TENN.	1975	High	7.5
3	CP	03414500	E FK OBEY R NR JAMESTOWN, TENN.	1968	Average	5.9
3	CP	03414500	E FK OBEY R NR JAMESTOWN, TENN.	1981	Low	4.3
4	CP	03415000	W FK OBEY R NR ALPINE, TENN.	1950	High	6.1
4	CP	03415000	W FK OBEY R NR ALPINE, TENN.	1968	Average	5.5
4	CP	03415000	W FK OBEY R NR ALPINE, TENN.	1981	Low	2.1
5	CP	03416000	WOLF RIVER NEAR BYRDSTOWN, TENN.	1975	High	9.7
5	CP	03416000	WOLF RIVER NEAR BYRDSTOWN, TENN.	1956	Average	5.7
5	CP	03416000	WOLF RIVER NEAR BYRDSTOWN, TENN.	1981	Low	3.1
6	HR	03418000	ROARING RIVER NEAR HILHAM, TENN.	1974	High	9.4
6	HR	03418000	ROARING RIVER NEAR HILHAM, TENN.	1968	Average	6.4
6	HR	03418000	ROARING RIVER NEAR HILHAM, TENN.	1966	Low	2.4
7	CP,HR	03420000	CALFKILLER R BELOW SPARTA, TENN.	1950	High	9.5
7	CP,HR	03420000	CALFKILLER R BELOW SPARTA, TENN.	1957	Average	9.0
7	CP,HR	03420000	CALFKILLER R BELOW SPARTA, TENN.	1966	Low	5.3
8	CP,HR	03421000	COLLINS R NEAR MCMINNVILLE, TENN.	1973	High	12.0
8	CP,HR	03421000	COLLINS R NEAR MCMINNVILLE, TENN.	1965	Average	9.3
8	CP,HR	03421000	COLLINS R NEAR MCMINNVILLE, TENN.	1981	Low	2.3
11	CB	03428000	W FK STONES R NR MURFREESBORO, TENN.	1951	High	8.0
11	CB	03428000	W FK STONES R NR MURFREESBORO, TENN.	1968	Average	6.5
11	CB	03428000	W FK STONES R NR MURFREESBORO, TENN.	1966	Low	1.1
12	CB	03428500	W FK STONES R NR SMYRNA, TENN.	1975	High	7.4
12	CB	03428500	W FK STONES R NR SMYRNA, TENN.	1970	Average	5.2
12	CB	03428500	W FK STONES R NR SMYRNA, TENN.	1981	Low	1.8
13	CB	03429000	STONES RIVER NEAR SMYRNA, TENN.	1950	High	5.2
13	CB	03429000	STONES RIVER NEAR SMYRNA, TENN.	1958	Average	4.9
13	CB	03429000	STONES RIVER NEAR SMYRNA, TENN.	1941	Low	1.3
14	CB	03430000	STONES RIVER ABOVE DONELSON, TENN.	Insufficient streamflow record		
15	CB	03430100	STONES R BL PERCY PRIEST DAM, TENN.	1950	High	6.8
15	CB	03430100	STONES R BL PERCY PRIEST DAM, TENN.	1961	Average	4.3
15	CB	03430100	STONES R BL PERCY PRIEST DAM, TENN.	1941	Low	1.3
16	CB	03431000	MILL CREEK NEAR ANTIOCH, TENN.	1973	High	10.1
16	CB	03431000	MILL CREEK NEAR ANTIOCH, TENN.	1970	Average	6.0
16	CB	03431000	MILL CREEK NEAR ANTIOCH, TENN.	1966	Low	1.8
17	CB	03431300	BROWNS CR AT FRGRNDS NASHVILLE, TENN.	Insufficient streamflow record		

Table 2.--*Net annual recharge rates estimated by hydrograph analysis and regression relation*--Continued

Station identi- fication number (fig. 2)	Major aquifers	Station number	Station name	Water year	Flow condition	Net annual recharge, in inches
18	CB	03431600	WHITES CR NR BORDEAUX, TENN.	1974	High	6.8
18	CB	03431600	WHITES CR NR BORDEAUX, TENN.	1972	Average	5.8
18	CB	03431600	WHITES CR NR BORDEAUX, TENN.	1971	Low	2.7
19	HR	03431800	SYCAMORE CR NR ASHLAND CITY, TENN.	1974	High	7.4
19	HR	03431800	SYCAMORE CR NR ASHLAND CITY, TENN.	1984	Average	4.9
19	HR	03431800	SYCAMORE CR NR ASHLAND CITY, TENN.	1971	Low	2.9
21	CB	03433500	HARPETH RIVER AT BELLEVUE, TENN.	1979	High	9.0
21	CB	03433500	HARPETH RIVER AT BELLEVUE, TENN.	1978	Average	5.2
21	CB	03433500	HARPETH RIVER AT BELLEVUE, TENN.	1981	Low	2.0
22	CB	03434500	HARPETH R NEAR KINGSTON SP, TENN.	1975	High	10.3
22	CB	03434500	HARPETH R NEAR KINGSTON SP, TENN.	1970	Average	5.8
22	CB	03434500	HARPETH R NEAR KINGSTON SP, TENN.	1941	Low	1.7
23	HR,CB	03435030	RED RIVER NEAR PORTLAND, TENN.	Insufficient streamflow record		
24	HR	03435500	RED RIVER NEAR ADAMS, TENN.	1950	High	12.0
24	HR	03435500	RED RIVER NEAR ADAMS, TENN.	1969	Average	6.2
24	HR	03435500	RED RIVER NEAR ADAMS, TENN.	1941	Low	2.3
25	HR	03436000	SULPHUR FK RED R NR ADAMS, TENN.	1974	High	7.1
25	HR	03436000	SULPHUR FK RED R NR ADAMS, TENN.	1970	Average	6.3
25	HR	03436000	SULPHUR FK RED R NR ADAMS, TENN.	1964	Low	2.6
26	HR	03436100	RED RIVER AT PORT ROYAL, TENN.	1975	High	11.3
26	HR	03436100	RED RIVER AT PORT ROYAL, TENN.	1968	Average	5.6
26	HR	03436100	RED RIVER AT PORT ROYAL, TENN.	1964	Low	2.8
27	HR	03436700	YELLOW CREEK NEAR SHILOH, TENN.	1979	High	13.0
27	HR	03436700	YELLOW CREEK NEAR SHILOH, TENN.	1972	Average	8.8
27	HR	03436700	YELLOW CREEK NEAR SHILOH, TENN.	1960	Low	6.4
28	BR	03455000	FRENCH BROAD R NR NEWPRORT, TENN.	1974	High	13.2
28	BR	03455000	FRENCH BROAD R NR NEWPRORT, TENN.	1964	Average	11.2
28	BR	03455000	FRENCH BROAD R NR NEWPRORT, TENN.	1956	Low	6.2
29	BR	03465500	NOLICHUCKY R AT EMBREEVILLE, TENN.	1974	High	17.1
29	BR	03465500	NOLICHUCKY R AT EMBREEVILLE, TENN.	1963	Average	9.6
29	BR	03465500	NOLICHUCKY R AT EMBREEVILLE, TENN.	1981	Low	6.0
31	BR	03470000	LITTLE PIGEON R AT SEVIERVILLE, TENN.	1973	High	13.5
31	BR	03470000	LITTLE PIGEON R AT SEVIERVILLE, TENN.	1964	Average	8.0
31	BR	03470000	LITTLE PIGEON R AT SEVIERVILLE, TENN.	1970	Low	7.7
33	VR	03487550	REEDY CREEK AT OREBANK, TENN.	1974	High	10.7
33	VR	03487550	REEDY CREEK AT OREBANK, TENN.	1984	Average	7.4
33	VR	03487550	REEDY CREEK AT OREBANK, TENN.	1969	Low	4.3
34	VR	03491000	BIG CREEK NEAR ROGERSVILLE, TENN.	1974	High	7.8
34	VR	03491000	BIG CREEK NEAR ROGERSVILLE, TENN.	1971	Average	5.7
34	VR	03491000	BIG CREEK NEAR ROGERSVILLE, TENN.	1981	Low	2.6
35	VR	03491300	BEECH CREEK AT KEPLER, TENN.	1974	High	6.7
35	VR	03491300	BEECH CREEK AT KEPLER, TENN.	1984	Average	5.8
35	VR	03491300	BEECH CREEK AT KEPLER, TENN.	1981	Low	2.7

Table 2.--*Net annual recharge rates estimated by hydrograph analysis and regression relation*--Continued

Station identification number (fig. 2)	Major aquifers	Station number	Station name	Water year	Flow condition	Net annual recharge, in inches
37	BR	03498500	LITTLE R NEAR MARYVILLE, TENN.	1974	High	13.0
37	BR	03498500	LITTLE R NEAR MARYVILLE, TENN.	1968	Average	9.4
37	BR	03498500	LITTLE R NEAR MARYVILLE, TENN.	1970	Low	8.8
38	BR	03518500	TELLICO R AT TELLICO PLAINS, TENN.	1973	High	25.1
38	BR	03518500	TELLICO R AT TELLICO PLAINS, TENN.	1968	Average	15.2
38	BR	03518500	TELLICO R AT TELLICO PLAINS, TENN.	1981	Low	7.9
39	VR	03519640	BAKER CREEK NEAR GREENBACK, TENN.	Insufficient streamflow record		
40	VR	03528000	CLINCH R ABOVE TAZEWELL, TENN.	1974	High	12.7
40	VR	03528000	CLINCH R ABOVE TAZEWELL, TENN.	1984	Average	7.5
40	VR	03528000	CLINCH R ABOVE TAZEWELL, TENN.	1981	Low	3.3
41	VR	03532000	POWELL RIVER NEAR ARTHUR, TENN.	1974	High	14.0
41	VR	03532000	POWELL RIVER NEAR ARTHUR, TENN.	1971	Average	6.6
41	VR	03532000	POWELL RIVER NEAR ARTHUR, TENN.	1981	Low	4.9
42	VR	03535000	BULLRUN CR NEAR HALLS CROSS, TENN.	1974	High	10.2
42	VR	03535000	BULLRUN CR NEAR HALLS CROSS, TENN.	1983	Average	7.2
42	VR	03535000	BULLRUN CR NEAR HALLS CROSS, TENN.	1981	Low	2.4
44	CP	03539600	DADDYS CR NR HEBBERTSBURG, TENN.	1962	High	9.6
44	CP	03539600	DADDYS CR NR HEBBERTSBURG, TENN.	1968	Average	5.4
44	CP	03539600	DADDYS CR NR HEBBERTSBURG, TENN.	1966	Low	4.0
45	CP	03539800	OBED RIVER NEAR LANCING, TENN.	1975	High	10.0
45	CP	03539800	OBED RIVER NEAR LANCING, TENN.	1983	Average	8.7
45	CP	03539800	OBED RIVER NEAR LANCING, TENN.	1981	Low	2.7
47	CP	03541300	BITTER CREEK NR OAKDALE, TENN.	Insufficient streamflow record		
48	VR	03543500	SEWEE CREEK NEAR DECATUR, TENN.	1974	High	11.3
48	VR	03543500	SEWEE CREEK NEAR DECATUR, TENN.	1965	Average	6.4
48	VR	03543500	SEWEE CREEK NEAR DECATUR, TENN.	1981	Low	2.7
49	BR	03556000	TURTLETOWN CR AT TURTLETOWN, TENN.	1950	High	21.0
49	BR	03556000	TURTLETOWN CR AT TURTLETOWN, TENN.	1961	Average	12.8
49	BR	03556000	TURTLETOWN CR AT TURTLETOWN, TENN.	1970	Low	10.3
51	VR	03565500	OOSTANAULA CR NEAR SANFORD, TENN.	1974	High	13.1
51	VR	03565500	OOSTANAULA CR NEAR SANFORD, TENN.	1977	Average	8.2
51	VR	03565500	OOSTANAULA CR NEAR SANFORD, TENN.	1981	Low	3.7
52	VR	03566420	WOLFTEVER CR NEAR OOLTEWAH, TENN.	1973	High	9.8
52	VR	03566420	WOLFTEVER CR NEAR OOLTEWAH, TENN.	1968	Average	6.4
52	VR	03566420	WOLFTEVER CR NEAR OOLTEWAH, TENN.	1981	Low	2.4
53	VR	03567500	S CHICKAMAUGA CR NEAR CHATT., TENN.	1973	High	13.0
53	VR	03567500	S CHICKAMAUGA CR NEAR CHATT., TENN.	1977	Average	6.7
53	VR	03567500	S CHICKAMAUGA CR NEAR CHATT., TENN.	1981	Low	2.8
54	VR,CP	03571000	SEQUATCHIE R NEAR WHITWELL, TENN.	1974	High	9.5
54	VR,CP	03571000	SEQUATCHIE R NEAR WHITWELL, TENN.	1968	Average	8.7
54	VR,CP	03571000	SEQUATCHIE R NEAR WHITWELL, TENN.	1981	Low	3.0

Table 2.--*Net annual recharge rates estimated by hydrograph analysis and regression relation*--Continued

Station identi- fication number (fig. 2)	Major aquifers	Station number	Station name	Water year	Flow condition	Net annual recharge, in inches
55	CP	03578000	ELK RIVER NEAR PELHAM, TENN.	1973	High	11.0
55	CP	03578000	ELK RIVER NEAR PELHAM, TENN.	1972	Average	8.8
55	CP	03578000	ELK RIVER NEAR PELHAM, TENN.	1981	Low	4.3
56	CP	03580300	BOILING FK CR AB WINCHESTER, TENN.	Insufficient streamflow record		
57	CB	03581500	W F MULBERRY CR AT MULBERRY, TENN.	Insufficient streamflow record		
58	CB	03583300	RICHLAND C NR CORNERSVILLE, TENN.	Insufficient streamflow record		
59	HR,CB	03583500	WEAKLEY CREEK NEAR BODENHAM, TENN.	Insufficient streamflow record		
60	CB	03584000	RICHLAND CR NEAR PULASKI, TENN.	1974	High	10.6
60	CB	03584000	RICHLAND CR NEAR PULASKI, TENN.	1965	Average	7.8
60	CB	03584000	RICHLAND CR NEAR PULASKI, TENN.	1966	Low	3.2
61	CB,HR,CP	03584500	ELK RIVER NEAR PROSPECT, TENN.	1950	High	7.2
61	CB,HR,CP	03584500	ELK RIVER NEAR PROSPECT, TENN.	1948	Average	4.1
61	CB,HR,CP	03584500	ELK RIVER NEAR PROSPECT, TENN.	1941	Low	3.7
62	HR	03588400	CHISHOLM CR AT WESTPOINT, TENN.	1973	High	18.8
62	HR	03588400	CHISHOLM CR AT WESTPOINT, TENN.	1977	Average	8.0
62	HR	03588400	CHISHOLM CR AT WESTPOINT, TENN.	1981	Low	5.4
63	HR	03588500	SHOAL CREEK AT IRON CITY, TENN.	1974	High	12.0
63	HR	03588500	SHOAL CREEK AT IRON CITY, TENN.	1968	Average	9.2
63	HR	03588500	SHOAL CREEK AT IRON CITY, TENN.	1981	Low	3.5
65	CB	03597000	GARRISON FORK AT FAIRFIELD, TENN.	Insufficient streamflow record		
66	CB	03597500	WARTRACE CR AT BELL BUCKLE, TENN.	1973	High	10.1
66	CB	03597500	WARTRACE CR AT BELL BUCKLE, TENN.	1957	Average	4.8
66	CB	03597500	WARTRACE CR AT BELL BUCKLE, TENN.	1969	Low	2.5
67	CB	03598000	DUCK R NEAR SHELBYVILLE, TENN.	1973	High	11.3
67	CB	03598000	DUCK R NEAR SHELBYVILLE, TENN.	1965	Average	6.6
67	CB	03598000	DUCK R NEAR SHELBYVILLE, TENN.	1966	Low	3.0
68	CB	03599000	BIG ROCK CR AT LEWISBURG, TENN.	Insufficient streamflow record		
69	CB	03599500	DUCK RIVER AT COLUMBIA, TENN.	1973	High	11.6
69	CB	03599500	DUCK RIVER AT COLUMBIA, TENN.	1968	Average	4.4
69	CB	03599500	DUCK RIVER AT COLUMBIA, TENN.	1981	Low	2.5
70	HR	03600500	BIG BIGBY CR AT SANDY HOOK, TENN.	1973	High	16.0
70	HR	03600500	BIG BIGBY CR AT SANDY HOOK, TENN.	1978	Average	9.0
70	HR	03600500	BIG BIGBY CR AT SANDY HOOK, TENN.	1981	Low	2.2
71	HR	03602500	PINEY RIVER AT VERNON, TENN.	1975	High	14.1
71	HR	03602500	PINEY RIVER AT VERNON, TENN.	1957	Average	5.0
71	HR	03602500	PINEY RIVER AT VERNON, TENN.	1966	Low	3.3
72	CB	03603000	DUCK R AB HURRICANE MILLS, TENN.	1973	High	15.1
72	CB	03603000	DUCK R AB HURRICANE MILLS, TENN.	1957	Average	6.2
72	CB	03603000	DUCK R AB HURRICANE MILLS, TENN.	1966	Low	3.2

Table 2.--*Net annual recharge rates estimated by hydrograph analysis and regression relation*--Continued

Station identification number (fig. 2)	Major aquifers	Station number	Station name	Water year	Flow condition	Net annual recharge, in inches
73	HR	03604000	BUFFALO R NEAR FLAT WOODS, TENN.	1973	High	14.3
73	HR	03604000	BUFFALO R NEAR FLAT WOODS, TENN.	1968	Average	8.7
73	HR	03604000	BUFFALO R NEAR FLAT WOODS, TENN.	1981	Low	4.8
74	HR	03604500	BUFFALO R NEAR LOBELVILLE, TENN.	1973	High	15.5
74	HR	03604500	BUFFALO R NEAR LOBELVILLE, TENN.	1968	Average	7.3
74	HR	03604500	BUFFALO R NEAR LOBELVILLE, TENN.	1981	Low	4.7
75	HR	03605555	TRACE CREEK ABOVE DENVER, TENN.	Periodic transbasin diversion of water may affect base flow.		

Table 3.--*Statistical summary of recharge rates during an average flow year by major aquifer*

Major aquifer	Number of basin estimates	Net annual recharge, in inches			
		Range	Mean	Median	Standard deviation
Cumberland Plateau aquifer	9	4.3- 8.9	6.5	5.7	1.8
Highland Rim aquifer	14	4.9- 9.8	7.4	7.6	1.7
Central Basin aquifer	15	4.1- 7.8	5.6	5.8	1.0
Valley and Ridge aquifer	12	5.2- 8.2	6.6	6.5	.9
Blue Ridge aquifer	8	8.0-16.8	11.7	10.9	3.0
All aquifers	63	4.1-16.8	7.3	6.5	2.5

estimate areal or regional aquifer hydraulic characteristics from streamflow data. The methods used in this investigation were developed by Olmsted and Hely (1962, p. A16-A18), Rorabaugh and Simons (1966, p. 12), and Trainer and Watkins (1975, p. 21-42). These methods are attractive because of the greater availability of surface-water data, and because the estimate obtained from streamflow characteristics represents a spatial integration of aquifer characteristics throughout the basin. Both the Theis equations and the methods based on streamflow characteristics are based on the assumption of ideal conditions within the aquifer. Because these conditions do not exist in the aquifers studied, it is recognized that these methods do not permit completely accurate or precise quantification of aquifer hydraulic characteristics. Estimates from both specific-capacity test data and streamflow data are presented and compared in the following sections.

Storage Coefficient

Procedure

The storage coefficient (S) is defined as the volume of water released from storage per unit surface area per unit change in head, a dimensionless ratio. In an unconfined aquifer, the storage coefficient may be approximated by gravity yield, which is defined as the volume of water that an unconfined aquifer yields by gravity per unit surface area per unit decline in water level. Olmsted and Hely (1962, p. A16-A18) estimated gravity yield from concurrent water-level and streamflow hydrographs using the following equation

$$Gy = \frac{\Delta Sg}{\Delta Hg}, \tag{5}$$

where
Gy is gravity yield (dimensionless);
ΔSg is the decrease in ground-water storage per unit area, in inches; and
ΔHg is the simultaneous decrease in ground-water head, in inches.

Base flow of the stream determined by hydrograph analysis was used to estimate ΔSg in the basin by assuming that recharge to and evapotranspiration from the water-table aquifer during the period of interest was minimal, and all base flow in the stream was from the saturated zone. The estimate of Gy represents conditions only in the zone of saturation above the level of the stream.

An example calculation of gravity yield for the drainage basin of Lick Creek at Mohawk illustrates the method (fig. 6). Integration of the base-flow recession curve from the streamflow hydrograph May 5, 1965, to May 25, 1965, yields a total volume of 1,723 ft^3/s-days (cubic feet per second times days), equivalent to 0.29 inches of water over the basin. During this period, water levels in a nearby observation well (Gr:J-2) declined 30 inches. Gravity yield is computed as 0.29/30, or 1 percent. This estimate is subject to error, because the water-table fluctuation in the vicinity of the observation well may not represent the average fluctuation in the drainage basin.

Results

Estimates of storage coefficient (approximated by gravity yield) for nine study basins for which concurrent water-level and streamflow records are available are summarized in table 4.

Table 4.--*Basin-specific estimates of storage coefficient*

[CP = Cumberland Plateau aquifer; HR = Highland Rim aquifer; CB = Central Basin aquifer; VR = Valley and Ridge aquifer; BR = Blue Ridge aquifer]

Station identification number (fig. 2)	Major aquifers	Station number	Station name	Storage coefficient
9	HR	03426800	E FK STONES R AT WOODBURY, TENN	0.025
10	CB	03427500	E FK STONES R NR LASCASSAS, TENN.	.010
20	CB	03432350	HARPETH RIVER AT FRANKLIN, TENN.	.002
30	VR	03467000	LICK CREEK AT MOHAWK, TENN.	.010
32	BR	03485500	DOE RIVER AT ELIZABETHTON, TENN.	.010
36	BR	03497300	LITTLE R ABOVE TOWNSEND, TENN.	.140
43	CP,VR	03538225	POPLAR CR NEAR OAK RIDGE, TENN.	.012
50	VR	03565300	S CHESTUEE CR NEAR BENTON, TENN.	.011
64	HR	03596000	DUCK R BELOW MANCHESTER, TENN.	.010

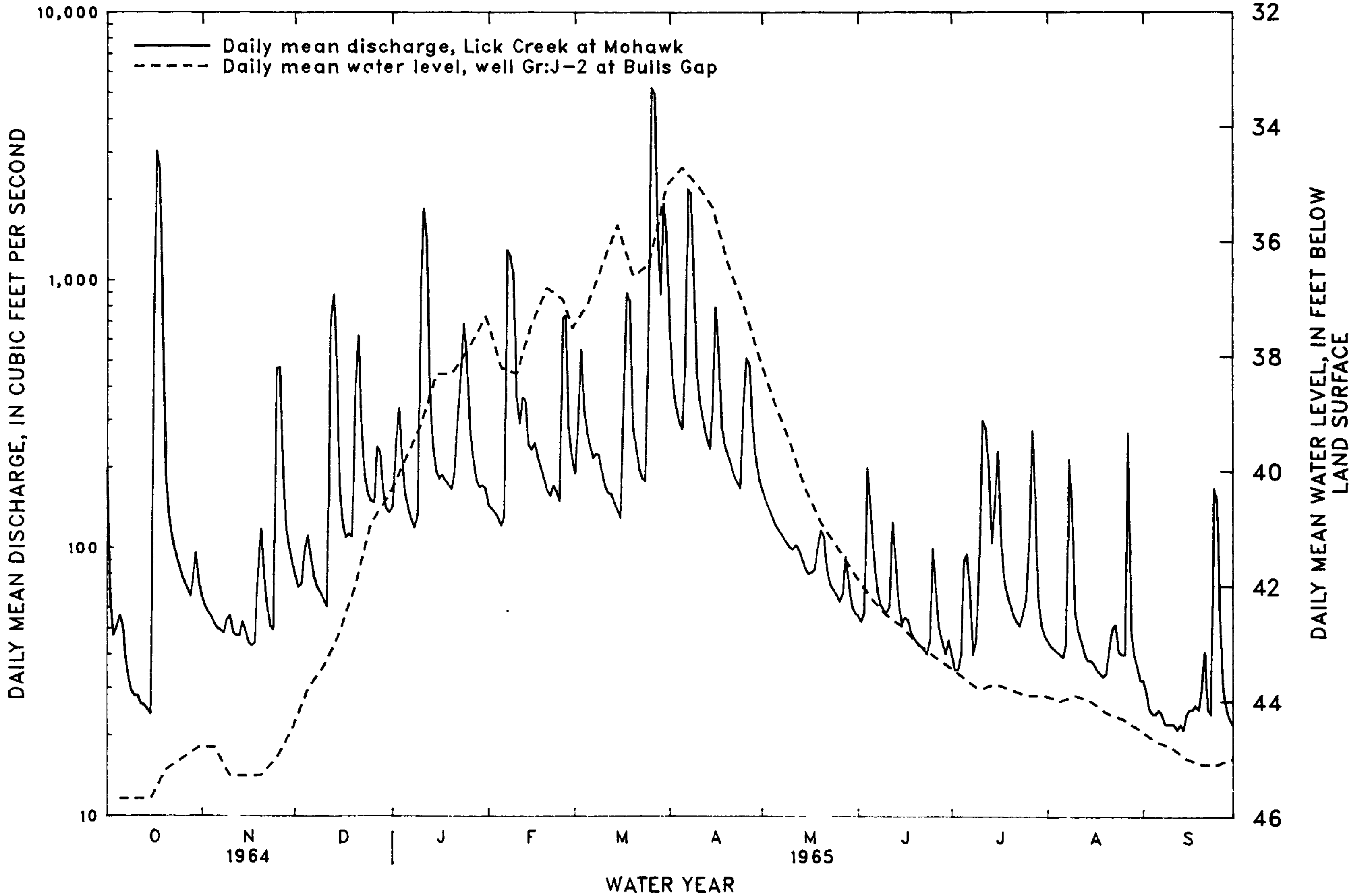


Figure 6.--Streamflow at Lick Creek at Mohawk, Tenn. (03467000), and water levels in well Gr:J-2 at Bulls Gap, Tenn., water year 1965.

The storage coefficient ranges from 0.002, for the Central Basin aquifer, to 0.140, for the Blue Ridge aquifer.

Estimates for seven of the nine study basins are within a narrow range of values, from 0.01 to 0.025. These estimates are in agreement with the value of 0.01 for specific yield for fractured bedrock aquifers with thick regolith, obtained by Trainer and Watkins (1975, p. 41). The relative proportion of saturated regolith to bedrock in the aquifer section is an important factor in determining the storage coefficient of the aquifer, because regolith is more porous than the bedrock material. The seven study basins are underlain by the Cumberland Plateau, Highland Rim, Valley and Ridge, and Blue Ridge aquifers, which are comprised of consolidated rocks with secondary porosity, overlain by a medium to thick cover of regolith. The value 0.01 is therefore used as an estimate for storage coefficient for all of the study basins underlain by one or more of these four aquifers. The value of 0.14 determined for the study basin above station number 03497300 is not believed to be representative of the Blue Ridge aquifer.

The estimates of storage coefficient for study basins underlain by the Central Basin aquifer, station numbers 03432350 and 03427500, are 0.002 and 0.01, respectively. The lower value can be explained by the lack of substantial amounts of regolith in the drainage basin for station 03432350. Because this condition exists throughout the inner part of the Central Basin province, a value of 0.002 for storage coefficient is assigned to all of the study basins in this area. A value of 0.01 for aquifer storage coefficient is assigned to study basins in the outer part of the Central Basin.

The estimates are grouped by major aquifer in table 5.

Diffusivity and Drainage Density

Procedure

Hydraulic diffusivity of an aquifer is defined as the ratio of the transmissive to storative properties of the aquifer, or, more formally, as the ratio of transmissivity to the storage coefficient. Transmissivity (T) is the rate at which water is transmitted through a unit width of the full thickness of the aquifer under a unit hydraulic gradient, expressed in feet squared per day. Rorabaugh (1960, p. 317) and Rorabaugh and Simons (1966, p. 12) related aquifer

Table 5.--*Summary of storage coefficient by major aquifer*

Major aquifer	Number of basin esti- mates	Storage coefficient: Range	Storage coefficient: Estimated representative value
Cumberland Plateau aquifer	1	0.010	0.010
Highland Rim aquifer	2	.010-.025	.010
Central Basin aquifer	2	.002-.010	Inner part - 0.002 Outer part - 0.010
Valley and Ridge aquifer	3	.010-.012	.010
Blue Ridge aquifer	2	.010-.140	.010

hydraulic diffusivity to the recession of base flow for an ideal aquifer. After a critical time period, base flow recedes exponentially with time. Through analogy to the physics of heat flow, Rorabaugh and Simons derived the equation

$$\underset{\text{(Diffusivity)}}{T/S} = \frac{0.933a^2}{\Delta t} \qquad (6)$$

where

T and S are as previously defined;

$\underline{a}$ is the distance from the ground-water divide to the adjacent stream, in feet; and

Δt is the streamflow recession index, which is the time required for base flow to recede through one log cycle, in days per cycle.

The equation assumes uniform, homogeneous, and isotropic conditions within the aquifer, equal distances from stream to ground-water divides throughout the basin, and water levels everywhere horizontal and equal to stream level prior to recharge events. In order to calculate a value of diffusivity from the streamflow recession index, the value of $\underline{a}$ must be known or estimated.

Values of $\underline{a}$ were obtained from estimates of drainage density (Dd) through the following relation:

$$a = \frac{1}{2Dd}\,. \qquad (7)$$

This relation assumes that ground-water basin divides correspond to surface drainage divides. Carlston and Langbein (U.S. Geological Survey, written commun., 1960) developed a line intersection method to estimate drainage density from the blue line network on topographic maps. A random pattern of lines is superimposed over a 1:24,000 topographic map of the basin, and the number of blue lines intersecting the superimposed pattern of lines is counted. The drainage density is approximated by

$$Dd = \pi/2 \ * \ N/L, \qquad (8)$$

where

Dd is drainage density, in number per mile;

N is the number of line intersections; and

L is the total length of the random pattern of lines, at map scale, in miles.

The estimation of drainage density for a selected, representative area of the drainage basin does not require subjective evaluation. Subjectivity does enter the procedure, however, in the selection of the representative area for each basin. The larger basins were subdivided into topographically similar units, for which estimates of drainage density were determined separately and then averaged together.

Results

Estimates of drainage density and corresponding hydraulic diffusivity (computed from equation 6) for the 75 study basins are listed in table 6. Statistical summaries of the estimates, organized by major aquifer, are listed in table 7. Drainage density ranges from 0.8 per mile, for a basin underlain by both the Highland Rim and Cumberland Plateau aquifers, to 4.3 per mile, for the Blue Ridge aquifer, with mean and median values both equal to 2.3 per mile. Variation within each aquifer is comparable to the variation observed between the aquifers. Hydraulic diffusivity ranges from 3,300 ft^2/d, for the Blue Ridge aquifer, to 130,000 ft^2/d, for a basin underlain by both the Highland Rim and Cumberland Plateau aquifers, with mean and median values of 31,000 and 23,000 ft^2/d, respectively. In general, diffusivity is lowest for basins underlain by the Blue Ridge aquifer (mean value 6,300 ft^2/d), and highest for basins underlain by the Cumberland Plateau aquifer (mean value 48,000 ft^2/d). Mean values of diffusivity for the Highland Rim, Central Basin, and Valley and Ridge aquifers are 31,000, 36,000, and 14,000 ft^2/d, respectively.

Table 6.--*Basin-specific estimates of drainage density, hydraulic diffusivity, and transmissivity*

[CP = Cumberland Plateau aquifer; HR = Highland Rim aquifer; CB = Central Basin aquifer; VR = Valley and Ridge aquifer; BR = Blue Ridge aquifer; ft^2/d, foot squared per day]

Station identi-fication number (fig. 2)	Major aquifers	Station number	Station name	Drainage density, in number per mile	Hydraulic diffusivity, in ft^2/d	Trans-missivity, in ft^2/d
1	CP	03408500	NEW RIVER AT NEW RIVER, TENN	1.8	58,000	580
2	CP	03409500	CLEAR FORK NEAR ROBBINS, TENN.	1.9	47,000	470
3	CP	03414500	E FK OBEY R NR JAMESTOWN, TENN.	1.5	57,000	570
4	CP	03415000	W FK OBEY R NR ALPINE, TENN.	1.8	35,000	350
5	CP	03416000	WOLF RIVER NEAR BYRDSTOWN, TENN.	1.2	70,000	700
6	HR	03418000	ROARING RIVER NEAR HILHAM, TENN.	1.0	92,000	920
7	CP,HR	03420000	CALFKILLER R BELOW SPARTA, TENN.	.8	130,000	1,300
8	CP,HR	03421000	COLLINS R NEAR MCMINNVILLE, TENN.	1.4	40,000	400
9	HR	03426800	E FK STONES R AT WOODBURY, TENN.	2.5	11,000	270
10	CB	03427500	E FK STONES R NR LASCASSAS, TENN.	2.5	21,000	190
11	CB	03428000	W FK STONES R NR MURFREESBORO,TENN	1.9	57,000	110
12	CB	03428500	W FK STONES R NR SMYRNA, TENN.	1.4	76,000	150
13	CB	03429000	STONES RIVER NEAR SMYRNA, TENN.	1.8	47,000	94
14	CB	03430000	STONES RIVER ABOVE DONELSON, TENN.	1.5	63,000	130
15	CB	03430100	STONES R BL PERCY PRIEST DAM, TENN.	1.5	63,000	130
16	CB	03431000	MILL CREEK NEAR ANTIOCH, TENN.	2.4	34,000	67
17	CB	03431300	BROWNS CR AT FRGRNDS NASHVILLE, TENN.	1.9	37,000	73
18	CB	03431600	WHITES CR NR BORDEAUX, TENN.	1.9	41,000	81
19	HR	03431800	SYCAMORE CR NR ASHLAND CITY, TENN.	1.4	33,000	330
20	CB	03432350	HARPETH RIVER AT FRANKLIN, TENN.	2.6	30,000	59
21	CB	03433500	HARPETH RIVER AT BELLEVUE, TENN.	2.3	37,000	73
22	CB	03434500	HARPETH R NEAR KINGSTON SP, TENN.	2.3	23,000	45
23	HR,CB	03435030	RED RIVER NEAR PORTLAND, TENN.	1.2	106,000	1,100
24	HR	03435500	RED RIVER NEAR ADAMS, TENN.	1.0	82,000	820
25	HR	03436000	SULPHUR FK RED R NR ADAMS, TENN.	1.5	54,000	540
26	HR	03436100	RED RIVER AT PORT ROYAL, TENN.	1.0	90,000	900
27	HR	03436700	YELLOW CREEK NEAR SHILOH, TENN.	2.5	10,000	100
28	BR	03455000	FRENCH BROAD R NR NEWPRORT, TENN.	3.7	3,000	33
29	BR	03465500	NOLICHUCKY R AT EMBREEVILLE, TENN.	3.4	6,000	57
30	VR	03467000	LICK CREEK AT MOHAWK, TENN.	3.3	9,000	90
31	BR	03470000	L PIGEON R AT SEVIERVILLE, TENN.	3.6	6,000	59
32	BR	03485500	DOE RIVER AT ELIZABETHTON, TENN.	2.6	9,000	93
33	VR	03487550	REEDY CREEK AT OREBANK, TENN.	2.1	14,000	140
34	VR	03491000	BIG CREEK NEAR ROGERSVILLE, TENN.	1.7	29,000	290
35	VR	03491300	BEECH CREEK AT KEPLER, TENN.	1.7	36,000	360
36	BR	03497300	LITTLE R ABOVE TOWNSEND, TENN.	4.1	3,000	470
37	BR	03498500	LITTLE R NEAR MARYVILLE, TENN.	4.3	4,000	39
38	BR	03518500	TELLICO R AT TELLICO PLAINS, TENN.	2.5	11,000	110
39	VR	03519640	BAKER CREEK NEAR GREENBACK, TENN.	2.3	14,000	140
40	VR	03528000	CLINCH R ABOVE TAZEWELL, TENN.	3.3	7,000	73
41	VR	03532000	POWELL RIVER NEAR ARTHUR, TENN.	1.8	20,000	200
42	VR	03535000	BULLRUN CR NEAR HALLS CROSS, TENN.	3.2	8,000	77
43	VR,CP	03538225	POPLAR CR NEAR OAK RIDGE, TENN.	3.0	11,000	130
44	CP	03539600	DADDYS CR NR HEBBERTSBURG, TENN.	2.3	39,000	390
45	CP	03539800	OBED RIVER NEAR LANCING, TENN.	2.7	25,000	250
46	CP	03540500	EMORY RIVER AT OAKDALE, TENN.	2.3	40,000	400
47	CP	03541300	BITTER CREEK NR OAKDALE, TENN.	2.5	37,000	370
48	VR	03543500	SEWEE CREEK NEAR DECATUR, TENN.	3.3	6,000	61
49	BR	03556000	TURTLETOWN CR AT TURTLETOWN, TENN.	1.7	8,000	82
50	VR	03565300	S CHESTUEE CR NEAR BENTON, TENN.	2.6	14,000	160

Table 6.--*Basin-specific estimates of drainage density, hydraulic diffusivity, and transmissivity*--Continued

Station identi- fication number (fig. 2)	Major aquifers	Station number	Station name	Drainage density, in number per mile	Hydraulic diffusivity, in ft^2/d	Trans- missivity, in ft^2/d
51	VR	03565500	OOSTANAULA CR NEAR SANFORD, TENN.	2.0	11,000	110
52	VR	03566420	WOLFTEVER CR NEAR OOLTEWAH, TENN.	3.0	9,000	92
53	VR	03567500	S CHICKAMAUGA CR NEAR CHATT., TENN.	2.7	7,000	74
54	VR,CP	03571000	SEQUATCHIE R NEAR WHITWELL, TENN.	1.9	21,000	210
55	CP	03578000	ELK RIVER NEAR PELHAM, TENN.	2.1	38,000	380
56	CP	03580300	BOILING FK CR AB WINCHESTER, TENN.	1.3	82,000	820
57	CB	03581500	W F MULBERRY CR AT MULBERRY, TENN.	2.1	42,000	84
58	CB	03583300	RICHLAND C NR CORNERSVILLE, TENN.	2.77	21,000	42
59	HR,CB	03583500	WEAKLEY CREEK NEAR BODENHAM,TENN.	3.1	7,000	68
60	CB	03584000	RICHLAND CR NEAR PULASKI, TENN.	2.8	14,000	28
61	CB,HR,CP	03584500	ELK RIVER NEAR PROSPECT, TENN.	2.7	12,000	120
62	HR	03588400	CHISHOLM CR AT WESTPOINT, TENN.	2.7	6,000	60
63	HR	03588500	SHOAL CREEK AT IRON CITY, TENN.	2.6	7,000	68
64	HR	03596000	DUCK R BELOW MANCHESTER, TENN.	1.9	21,000	210
65	CB	03597000	GARRISON FORK AT FAIRFIELD, TENN.	2.2	25,000	50
66	CB	03597500	WARTRACE CR AT BELL BUCKLE, TENN.	2.2	39,000	78
67	CB	03598000	DUCK R NEAR SHELBYVILLE, TENN.	2.4	11,000	22
68	CB	03599000	BIG ROCK CR AT LEWISBURG, TENN.	2.6	27,000	53
69	CB	03599500	DUCK RIVER AT COLUMBIA, TENN.	1.8	41,000	81
70	HR	03600500	BIG BIGBY CR AT SANDY HOOK, TENN.	2.6	9,000	93
71	HR	03602500	PINEY RIVER AT VERNON, TENN.	3.3	4,000	43
72	CB	03603000	DUCK R AB HURRICANE MILLS, TENN.	2.2	15,000	30
73	HR	03604000	BUFFALO R NEAR FLAT WOODS, TENN.	3.0	6,000	60
74	HR	03604500	BUFFALO R NEAR LOBELVILLE, TENN.	3.0	6,000	56
75	HR	03605555	TRACE CREEK ABOVE DENVER, TENN.	1.9	27,000	270

Transmissivity

Procedure

A basin-specific estimate of aquifer transmissivity (T) was computed as the product of estimates of hydraulic diffusivity (defined as the ratio T/S) and the storage coefficient (S) for each study basin. This value represents the average transmissive property of the water-bearing materials in the zone of saturation above the level of the stream.

Site-specific estimates of transmissivity were computed from specific-capacity tests using the equations derived by Theis (1963, p. 333). The equations assume that the aquifer is homogeneous, isotropic, and of infinite areal extent, that the well penetrates the full thickness of the aquifer, and that water is discharged instantaneously from storage. Test data required for the calculation include the constant pumping rate, the decline in water level measured in the discharging well, the length of the pumping period, the effective radius of the well, and the storage coefficient of the aquifer. The ratio of pumping rate to decline in water level, or drawdown, in the discharging well is known as specific capacity. Values for the storage coefficient were assigned to each well site, based on the regionalized value of the storage coefficient, as discussed in the section under that heading.

Results

Basin-specific estimates of transmissivity calculated from hydraulic diffusivity and storage coefficient for each study basin are listed in table 6. The values range from 22 ft^2/d (for the Central Basin aquifer) to 1,300 ft^2/d (for a basin underlain by both the Highland Rim and Cumberland Plateau aquifer), or through approximately two orders of magnitude, with an average of 240 ft^2/d. Statistical summaries of the estimates, organized by major aquifer, are listed in table 8. Variation within each unit is large; standard deviation values are comparable to (and, for the Highland Rim and Blue Ridge aquifers, even exceed) corresponding mean or median values. In general, transmissivity is highest in the Cumberland Plateau aquifer (mean value of 480 ft^2/d) and lowest in the Central Basin aquifer (mean value of 79 ft^2/d). The low values estimated for the Central Basin aquifer result from the low value of storage coefficient (a factor in the estimation procedure) assigned to this aquifer. Mean values for the Highland Rim, Valley and Ridge, and Blue Ridge aquifers are 320, 140, and 120 ft^2/d, respectively.

Data from 130 published specific-capacity tests in Middle and East Tennessee (Wilson, 1965; McMaster and Hubbard, 1970; Burchett, 1977; Rima and others, 1977; Hollyday and Goddard, 1979; Rima and Goddard, 1979; Zurawski, 1979; Zurawski and Burchett, 1980; Burchett and others, 1983; Bradley, 1984) and from tests in the files of the U.S. Geological Survey Tennessee District office and of several drillers in Tennessee are listed in table 9. Test well locations are shown in figure 7. Transmissivity values are estimated from 118 of the tests; where test

Table 7.--*Statistical summary of drainage density and hydraulic diffusivity by major aquifer*

Major aquifer	Number of basin estimates	Range	Mean	Median	Standard deviation
		Drainage density, in number per mile			
Cumberland Plateau aquifer	11	1.2- 2.7	1.9	1.9	0.5
Highland Rim aquifer	15	1.0- 3.3	2.1	2.5	.8
Central Basin aquifer	21	1.4- 2.8	2.1	2.2	.4
Valley and Ridge aquifer	13	1.7- 3.3	2.5	2.6	.6
Blue Ridge aquifer	8	1.7- 4.3	3.2	3.5	.9
All aquifers	75	.8- 4.3	2.3	2.3	.7
		Hydraulic diffusivity, in feet squared per day			
Cumberland Plateau aquifer	11	25,000- 82,000	48,000	40,000	17,000
Highland Rim aquifer	15	4,300- 92,000	31,000	11,000	33,000
Central Basin aquifer	21	11,000- 76,000	36,000	37,000	17,000
Valley and Ridge aquifer	13	6,000- 36,000	14,000	11,000	9,200
Blue Ridge aquifer	8	3,300- 11,000	6,300	5,800	2,800
All aquifers	75	3,300-130,000	31,000	23,000	7,100

data are inadequate to permit calculation of a transmissivity value, specific capacity is reported alone. Site-specific estimates of transmissivity range from 2 ft^2/d (for the Valley and Ridge aquifer) to 93,000 ft^2/d (for the Central Basin aquifer), averaging 2,600 ft^2/d. Statistical summaries of the estimates, organized by major aquifer, are listed in table 8.

The variation within each aquifer is even more marked than that observed in the distribution of basin-specific estimates; for all aquifers, the values for standard deviation far exceed corresponding mean or median values. The heterogeneity of aquifer properties may explain the larger range of site-specific estimates as compared to basin-specific estimates. A basin-specific estimate represents an average of widely varying conditions, whereas a site-specific estimate represents a smaller set of conditions.

In general, site-specific estimates are much higher than the basin-specific estimates. Specific-capacity test data may be biased because generally only the more productive areas and intervals of the aquifer have been tested. The relative ranking among the major aquifers is similar for both types of estimates, except that ranking for the Central Basin aquifer is lowest for the basin-specific estimates and highest for the site-specific estimates, and the relative ranking of the Valley and Ridge and Blue Ridge aquifers are reversed. Mean values of site-specific estimates of transmissivity for the Cumberland Plateau, Highland Rim, Central Basin, Valley and Ridge, and Blue Ridge aquifers are 2,800, 1,200, 7,800, 390, and 650 ft^2/d, respectively.

Table 8.--*Statistical summary of transmissivity by major aquifer*

Major aquifer	Number of basin estimates	Range	Mean	Median	Standard deviation
Transmissivity (basin-specific estimate, in feet squared per day)					
Cumberland Plateau aquifer	11	250- 820	480	400	170
Highland Rim aquifer	15	43- 920	320	210	320
Central Basin aquifer	21	22- 190	79	73	42
Valley and Ridge aquifer	13	61- 360	140	110	92
Blue Ridge aquifer	8	33- 470	120	71	140
All aquifers	75	22-1,300	240	110	270
Transmissivity (site-specific estimate, in feet squared per day)					
Cumberland Plateau aquifer	10	29-24,000	2,800	300	7,500
Highland Rim aquifer	27	76- 4,400	1,200	550	1,300
Central Basin aquifer	27	140-93,000	7,800	2,600	19,000
Valley and Ridge aquifer	18	2- 2,900	390	110	700
Blue Ridge aquifer	36	9- 8,400	650	220	1,500
All aquifers	118	2-93,000	2,600	460	9,900

Table 9.--*Specific-capacity tests and site-specific estimates of transmissivity*

[Test well numbers correspond to numbers on figure 7; CP = Cumberland Plateau aquifer; HR = Highland Rim aquifer; CB = Central Basin aquifer; VR = Valley and Ridge aquifer; BR = Blue Ridge aquifer; gal/min, gallon per minute; gal/min/ft, gallon per minute per foot; ft^2/d, foot squared per day; -- = no data]

Test well number (fig. 7)	County	Major aquifers	Depth of well in feet	Length of test in hours	Average pumping rate during test, in gal/min	Draw-down, in ft	Specific capa-city, in gal/min/ft	Trans-missi-vity, in ft^2/d
1	COFFEE	CB	165.0	17.90	230.0	--	4.6	1,200
2	COFFEE	CB	125.0	8.40	270.0	--	10	2,600
3	COFFEE	CB	70.0	19.30	290.0	--	11	2,900
4	COFFEE	CB	122.0	24.00	330.0	--	12	3,100
5	COFFEE	CB	152.0	10.00	300.0	--	19	4,900
6	COFFEE	CB	25.0	4.00	100.0	--	11	2,700
7	COFFEE	CB	95.0	10.30	250.0	--	8.2	2,100
8	COFFEE	CB	84.0	22.00	400.0	--	15	3,800
9	COFFEE	CB	126.0	24.00	500.0	--	14	3,600
10	COFFEE	CB	107.0	23.70	500.0	--	18	4,900
11	DICKSON	HR	400.0	2.00	110.0	47.4	2.3	550
12	DICKSON	HR	340.0	1.00	175.0	128.7	1.4	310
13	DICKSON	HR	280.0	2.00	100.0	54.1	1.9	440
14	DICKSON	HR	280.0	1.50	225.0	27.7	8.1	1,900
15	DICKSON	HR	300.0	2.00	300.0	87.9	3.4	810
16	DICKSON	HR	300.0	2.00	135.0	36.4	3.7	880
17	DICKSON	HR	250.0	1.50	270.0	46.6	5.8	1,400
18	DICKSON	HR	160.0	4.00	210.0	16.5	13	3,100
19	DICKSON	HR	240.0	6.40	85.0	83.1	1.0	260
20	DICKSON	HR	200.0	4.00	72.0	100.8	.71	180
21	WILLIAMSON	HR	185.0	8.00	20.0	69.8	.30	76
22	WILLIAMSON	HR	200.0	72.00	55.0	50.1	1.1	320
23	WILLIAMSON	HR	185.0	8.00	40.0	70.0	.60	150
24	WILLIAMSON	HR	206.0	72.00	43.0	121.7	.40	120
25	HAMILTON	VR	340.0	4.75	60.0	25.6	2.3	560
26	GILES	HR	106.0	9.65	112.0	59.1	1.9	490
27	FRANKLIN	HR	200.0	4.25	20.0	51.3	.39	95
28	FRANKLIN	HR	105.0	4.00	95.0	5.3	18	4,400
29	FRANKLIN	HR	160.0	5.33	48.0	46.5	1.0	260
30	HAMILTON	VR	400.0	3.00	90.0	168.4	.53	130
31	HAMILTON	VR	300.0	4.33	104.0	156.7	.35	86
32	RUTHERFORD	CB	275.0	11.00	250.0	78.3	3.2	860
33	RHEA	VR	160.0	6.92	160.0	42.3	3.8	950
34	LEWIS	HR	225.0	24.00	495.0	32.0	16	4,200
35	LEWIS	HR	259.0	48.00	285.0	54.6	5.2	1,400
36	LEWIS	HR	110.0	6.67	300.0	18.4	16	4,100
37	WILLIAMSON	CB	206.0	26.50	250.0	55.0	4.5	1,300
38	DAVIDSON	CB	147.0	.85	500.0	2.0	250	48,000
39	HAMILTON	VR	315.0	10.00	205.0	65.8	3.1	780
40	HAMILTON	VR	175.0	24.50	1439.0	130.8	11	2,900
41	HAMILTON	VR	290.0	22.50	657.0	206.6	3.2	830
42	MORGAN	CP	970.0	24.00	40.0	135.3	.29	74
43	MORGAN	CP	300.0	18.73	40.0	24.8	1.6	430
44	GRUNDY	CP	410.0	24.00	175.0	78.9	2.2	580
45	LINCOLN	HR	126.5	24.00	90.0	51.0	1.8	490
46	LINCOLN	HR	145.0	24.00	104.0	40.0	2.6	710
47	LINCOLN	HR	126.5	2.00	37.0	10.0	3.7	860
48	LINCOLN	HR	136.0	2.00	30.0	28.3	1.1	260
49	MAURY	CB	145.0	23.10	--	--	44	12,000
50	MAURY	CB	206.0	24.00	--	--	1.0	270

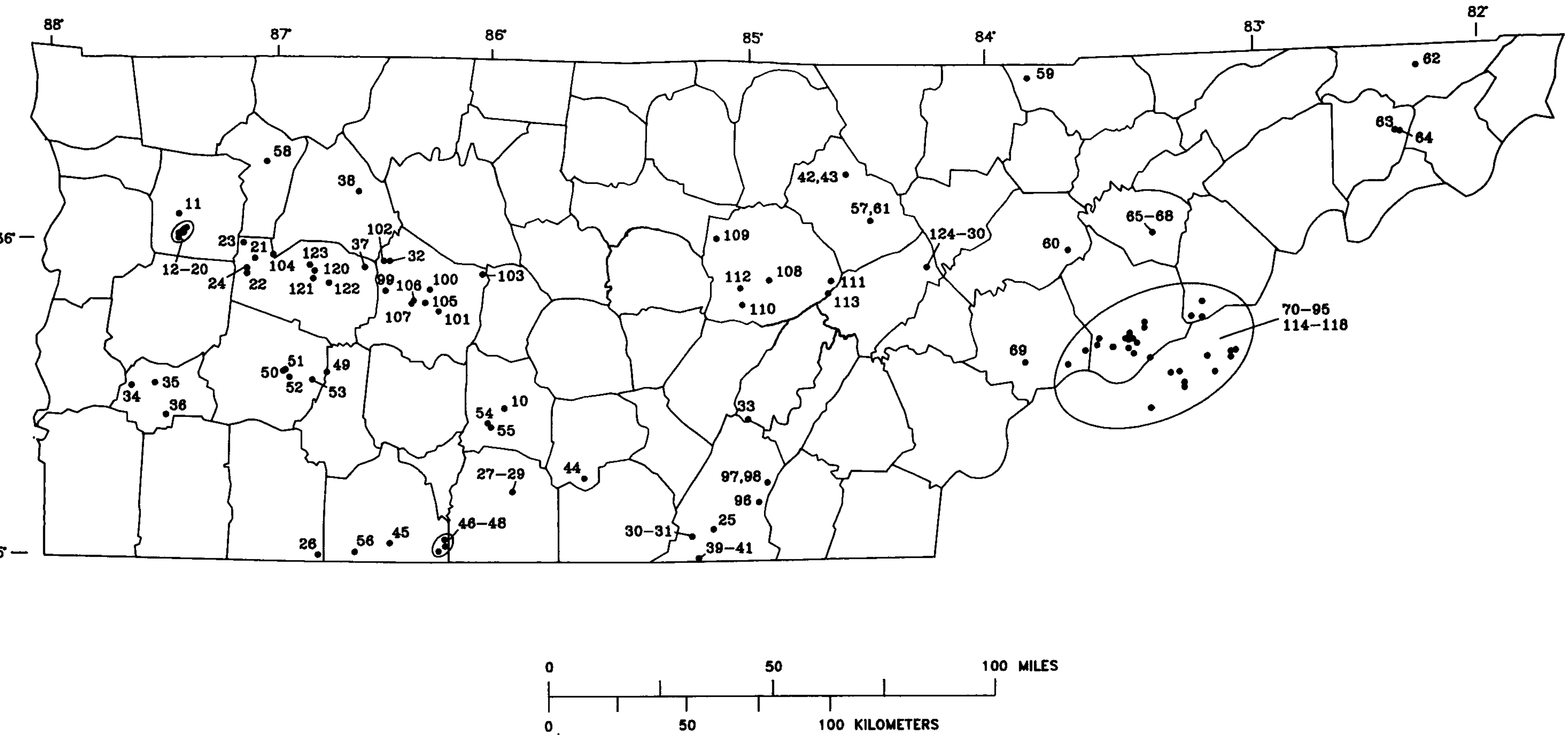
Table 9.--*Specific-capacity tests and site-specific estimates of transmissivity*--Continued

Test well number (fig. 7)	County	Major aquifers	Depth of well in feet	Length of test in hours	Average pumping rate during test, in gal/min	Draw-down, in ft	Specific capa-city, in gal/min/ft	Trans-missi-vity, in ft^2/d
51	MAURY	CB	207.0	6.67	--	--	0.90	230
52	MAURY	CB	206.0	7.25	--	--	15	3,700
53	MAURY	CB	80.0	15.10	--	--	12	3,200
54	COFFEE	CB	268.0	2.60	--	--	2.2	530
55	COFFEE	CB	268.0	4.40	--	--	7.3	1,800
56	LINCOLN	HR	87.0	24.00	190.0	39.0	4.9	1,300
57	MORGAN	CP	302.0	24.00	--	--	6.4	1,700
58	CHEATHAM	HR	--	--	--	--	.05	--
59	CLAIBORNE	HR	190.0	2.00	--	--	12	2,700
60	KNOX	VR	--	--	--	--	.01	--
61	MORGAN	CP	--	--	--	--	3.6	--
62	SULLIVAN	VR	--	--	--	--	.06	--
63	WASHINGTON	VR	--	--	--	--	.02	--
64	WASHINGTON	VR	--	--	--	--	.04	--
65	JEFFERSON	VR	290.0	1.00	--	--	.67	150
66	JEFFERSON	VR	390.0	1.00	--	--	.68	140
67	JEFFERSON	VR	408.0	1.00	--	--	.30	66
68	JEFFERSON	VR	400.0	1.00	--	--	2.1	430
69	BLOUNT	BR	185.0	2.00	6.0	34.0	.18	42
70	SWAIN	BR	150.0	2.00	8.0	17.0	.47	110
71	BLOUNT	BR	350.0	2.00	90.0	6.5	14	3,200
72	HAYWOOD	BR	165.0	2.00	35.0	60.0	.58	140
73	HAYWOOD	BR	188.0	2.00	25.0	60.0	.41	96
74	HAYWOOD	BR	184.0	2.00	67.0	67.0	1.0	230
75	HAYWOOD	BR	152.0	2.00	40.0	110.0	.36	84
76	SEVIER	BR	87.0	2.00	10.0	7.5	1.3	310
77	SEVIER	BR	212.0	2.00	6.5	110.0	.06	14
78	SWAIN	BR	148.0	2.00	70.0	56.0	1.3	290
79	COCKE	BR	188.0	2.00	15.0	--	.30	70
80	SWAIN	BR	125.0	2.00	108.0	34.0	3.2	740
81	SEVIER	BR	215.0	2.00	50.0	55.0	.91	210
82	COCKE	BR	202.0	2.00	5.0	115.0	.04	9
83	COCKE	BR	125.0	2.00	4.0	43.0	.09	21
84	COCKE	BR	194.0	2.00	108.0	50.0	2.2	500
85	SEVIER	BR	125.0	2.00	125.0	60.0	2.1	490
86	SEVIER	BR	150.0	2.00	10.0	20.0	.50	120
87	SWAIN	BR	150.0	2.00	45.0	45.0	1.0	230
88	SEVIER	BR	225.0	2.00	4.5	45.0	.10	23
89	SEVIER	BR	125.0	2.00	72.0	31.0	2.3	540
90	SWAIN	BR	99.0	2.00	110.0	27.0	4.1	950
91	SWAIN	BR	150.0	2.00	135.0	26.0	5.2	1,200
92	SEVIER	BR	120.0	2.00	50.0	50.0	1.0	230
93	SWAIN	BR	148.0	2.00	28.0	123.0	.23	54
94	BLOUNT	BR	130.0	2.00	10.0	40.0	.25	58
95	SEVIER	BR	150.0	2.00	20.0	35.0	.57	130
96	HAMILTON	BR	250.0	2.0	250.0	21.2	12	2,700
97	HAMILTON	BR	247.0	1.2	--	--	37	8,400
98	BRADLEY	BR	120.0	2.50	--	--	3.3	780
99	RUTHERFORD	CB	95.0	--	97.0	30.0	3.2	--
100	RUTHERFORD	CB	93.0	--	50.0	63.0	.79	--

Table 9.--*Specific-capacity tests and site-specific estimates of transmissivity*--Continued

Test well number (fig. 7)	County	Major aquifers	Depth of well in feet	Length of test in hours	Average pumping rate during test, in gal/min	Draw-down, in ft	Specific capa-city, in gal/min/ft	Trans-missi-vity, in ft^2/d
101	RUTHERFORD	CB	63.0	--	60.0	40.0	1.5	--
102	RUTHERFORD	CB	135.0	--	60.0	90.0	.67	--
103	RUTHERFORD	CB	100.0	--	60.0	40.0	1.5	--
104	RUTHERFORD	CB	90.0	--	110.0	2.0	55	--
105	RUTHERFORD	CB	175.0	2.00	40.0	76.0	.53	140
106	RUTHERFORD	CB	175.0	4.00	50.0	20.0	2.5	670
107	RUTHERFORD	CB	250.0	3.00	100.0	50.0	2.0	530
108	CUMBERLAND	CP	312.0	2.00	9.0	22.0	.46	110
109	CUMBERLAND	CP	60.0	2.50	10.0	14.5	.69	160
110	CUMBERLAND	CP	72.0	2.00	10.0	16.0	.63	150
111	CUMBERLAND	CP	60.0	2.50	10.0	3.6	2.8	660
112	CUMBERLAND	CP	130.0	1.16	10.0	76.0	.13	29
113	CUMBERLAND	CP	99.0	.75	10.0	.1	110	24,000
114	SEVIER	BR	230.0	5.00	80.0	74.8	.92	230
115	SEVIER	BR	255.0	6.00	60.0	92.8	.60	150
116	SEVIER	BR	230.0	7.00	57.0	97.9	.60	150
117	SEVIER	BR	200.0	7.50	20.0	10.0	.20	51
118	SEVIER	BR	230.0	5.00	67.0	20.1	2.1	520
119	SEVIER	BR	230.0	4.00	67.0	46.0	1.1	270
120	WILLIAMSON	CB	153.0	8.00	204.0	37.5	5.4	1,400
121	WILLIAMSON	CB	203.0	8.00	107.0	2.5	42	12,000
122	WILLIAMSON	CB	253.0	8.00	111.0	68.8	.60	160
123	WILLIAMSON	CB	192.0	8.00	200.0	.6	360	93,000
124	ROANE	VR	--	--	--	--	--	[a]30
125	ROANE	VR	--	--	--	--	--	[a]2
126	ROANE	VR	--	--	--	--	--	[a]4
127	ROANE	VR	--	--	--	--	--	[a]3
128	ROANE	VR	--	--	--	--	--	[a]6
129	ROANE	VR	--	--	--	--	--	[a]4
130	ROANE	VR	--	--	--	--	--	[a]3

[a]Value for transmissivity is estimated from a large number of specific-capacity tests performed within a small (20 square mile) area in the upper 100 feet of a single geologic formation (Z. Bailey, USGS, written commun., 1988).



EXPLANATION

•25 TEST WELL AND NUMBER (See table 9)

Figure 7.––Location of test wells.

SUMMARY

Quantification of the hydrologic and hydraulic characteristics of the bedrock aquifers in Middle and East Tennessee is essential for effective development of ground-water resources in this area of increasing demand for water. This report provides estimates of aquifer recharge rates, storage coefficient, diffusivity, and transmissivity for representative drainage basins in Middle and East Tennessee. This information will help identify areas in Middle and East Tennessee having high potential for development of ground-water supplies. All of the methods used are based on assumption of ideal conditions in the aquifer; for example, homogeneous and isotropic materials. Because ideal conditions do not exist throughout the aquifers studied, the estimates may not accurately or precisely quantify the aquifer properties in some areas.

Aquifer recharge rates are estimated for representative "high," "average," and "low" flow years for 63 drainage basins using hydrograph analysis techniques. Net annual recharge during average flow years ranges from 4.1 to 16.8 inches. Estimates of storage coefficient, determined from hydrologic analysis of concurrent water-level and streamflow hydrographs for nine drainage basins, range from 0.002 to 0.140. Estimates of aquifer hydraulic diffusivity are derived from estimates of the streamflow recession index and drainage density for 75 drainage basins; values range from 3,300 to 130,000 ft^2/d. Both basin-specific and site-specific estimates of transmissivity are computed from estimates of hydraulic diffusivity and specific-capacity test data, respectively. Transmissivity values range from 22 to 1,300 ft^2/d for basin-specific estimates, and from 2 to 93,000 ft^2/d for site-specific estimates. Discrepancies between basin-specific and site-specific estimates of transmissivity for the same area are attributed to the small scale of heterogeneity of aquifer properties relative to the size of the basins, and to specific-capacity data that generally are available only for the more productive areas and intervals of the aquifer. The drainage basins have been grouped according to the underlying major aquifer, then statistical descriptions applied to each group, in order to define the areal distribution of these characteristics.

The rocks of the Cumberland Plateau aquifer generally are covered with only a few feet of regolith; water is stored mainly in the bedrock, and moves rapidly through fractures, faults, and bedding-plane openings towards surface drains. Estimated mean recharge is 6.5 in/yr. Transmissivity values estimated from base-flow analysis are highest for this aquifer, averaging 480 ft^2/d. Transmissivity values estimated from specific-capacity data average 2,800 ft^2/d.

Bedrock of the Highland Rim aquifer is covered with up to 100 feet of regolith. Water is stored in the regolith and in solution-widened fractures in the bedrock and moves through these fractures. Estimated mean recharge is 7.4 in/yr. The mean value for transmissivity estimated from base-flow analysis is 320 ft^2/d; transmissivity values estimated from specific-capacity data average 1,200 ft^2/d.

Water-bearing openings in the carbonate rocks of the Central Basin aquifer are restricted to solution-enlarged vertical joints and horizontal bedding planes. Regolith cover is variable, although it is mainly thin to absent in the inner part of the basin. Estimated recharge rates are lowest for this aquifer, averaging 5.6 in/yr. Transmissivity values estimated from base-flow analysis are lowest for this aquifer, averaging 79 ft^2/d; transmissivity values estimated from specific-capacity data, however, are highest for this aquifer, averaging 7,800 ft^2/d.

The Valley and Ridge aquifer is composed of several geohydrologic terranes. Dolomitic limestone, with extensive networks of solution-enlarged fractures and thick regolith cover, crops

out in alternating belts with tight sandstone, shale, and clayey limestone with thin regolith cover. Estimated mean recharge is 6.6 in/yr. Mean value for transmissivity estimated from base-flow analysis is 140 ft^2/d; transmissivity values estimated from specific-capacity data are lowest for this aquifer, with a mean value of 390 ft^2/d.

The dense fractured bedrock of the Blue Ridge aquifer is covered in places with a thick mantle of regolith (as much as 100 feet). Water is stored in the regolith and moves through fractures in the bedrock. Estimated recharge rates are substantially higher for this aquifer, averaging 11.7 in/yr. Mean value of transmissivity estimated from base-flow analysis is 120 ft^2/d; transmissivity values estimated from specific-capacity data average 650 ft^2/d.

Gravity drainage characterizes ground-water flow in most surficial bedrock aquifers in Tennessee. Although the basin estimates of storage coefficient range from 0.002 to 0.140, most estimates are within a narrow range of values, from 0.01 to 0.025. Accordingly, storage coefficient is estimated to be 0.01 for all aquifers studied, with the exception of the aquifers in the inner part of the Central Basin, for which storage coefficient is estimated to be 0.002.

REFERENCES CITED

Bevans, H. E., 1986, Estimating stream-aquifer interactions in coal areas of eastern Kansas by using streamflow records, *in* Subitzky, Seymour, ed., Selected papers in the hydrologic sciences: U.S. Geological Survey Water-Supply Paper 2290, p. 51-64.

Bingham, R. H., 1986, Regionalization of low-flow characteristics of Tennessee streams: U.S. Geological Survey Water-Resources Investigations Report 85-4191, 63 p.

Bradley, M. W., 1984, Ground water in the Dickson area of the western Highland Rim of Tennessee: U.S. Geological Survey Water-Resources Investigations Report 82-4088, 42 p.

Bradley, M. W., and Hollyday, E. F., 1985, Tennessee ground-water resources, *in* National water summary Ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, p. 391-396.

Burchett, C. R., 1977, Water resources of the upper Duck River basin, central Tennessee: Tennessee Division of Water Resources, Water Resources Series No. 12, 103 p.

Burchett, C. R., Zurawski, Ann, Sparkes, A. K., and Hollyday, E. F., 1983, Ground water in carbonate rocks and regolith in the Fairview area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 83-4134, 38 p.

Daniel, J. F., 1976, Estimating groundwater evapotranspiration from streamflow records: Water Resources Research, v. 12, no. 3, p. 360-364.

Faye, R. E., and Mayer, G. C., 1989, Ground-water flow and stream-aquifer relations in the northern Coastal Plain of Georgia and adjacent parts of Alabama and South Carolina: U.S. Geological Survey Water-Resources Investigations Report 88-4143.

Hollyday, E. F., and Goddard, P. L., 1979, Ground-water availability in carbonate rocks of the Dandridge Area, Jefferson, County, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 79-1263, 50 p.

McMaster, W. M., and Hubbard, E. F., 1970, Water resources of the Great Smoky Mountains National Park, Tennessee and North Carolina: U.S. Geological Survey Hydrologic Investigations Atlas, HA-420, 2 sheets.

Miller, R. A., 1974, The geologic history of Tennessee: Tennessee Division of Geology Bulletin 74, p. 3-7.

Olmsted, F. H., and Hely, A. G., 1962, Relation between ground water and surface water in Brandywine Creek Basin, Pennsylvania: U.S. Geological Survey Professional Paper 417-A, 21 p.

Rima, D. R., and Goddard, P. L., 1979, Ground-water resources in the metropolitan region of Nashville, Tennessee: U.S. Army Corps of Engineers, Nashville District, 44 p.

Rima, D. R., Moran, M.S., and Woods, E. J., 1977, Ground-water supplies in the Murfreesboro area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 79-86, 76 p.

Rorabaugh, M. I., 1960, Use of water levels in estimating aquifer constants in finite aquifer: International Association of Scientific Hydrology Publication 52, p. 314-323.

----- 1964, Estimating changes in bank storage and ground-water contribution to streamflow: International Association of Science and Hydrology Publication 63, p. 432-441.

Rorabaugh, M. I., and Simons, W. D., 1966, Exploration of methods of relating ground water to surface water, Columbia River basin—Second Phase: U.S. Geological Survey Open-File Report, 62 p.

Springer, M. E., and Elder, J. A., 1980, Soils of Tennessee: U.S. Soil Conservation Service Bulletin 596, 64 p.

Theis, C. V., 1935, Relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: American Geophysical Union Transactions, pt. 2, p. 519-524.

----- 1963, Estimating the transmissibility of a water-table aquifer from the specific capacity of a well, *in* Bentall, Ray (compiler), Methods of determining permeability, transmissibility and drawdown: U.S. Geological Survey Water-Supply Paper 1536-I, p. 331-341.

Trainer, F. W., and Watkins, F. A., 1975, Geohydrologic reconnaissance of the upper Potomac River basin: U.S. Geological Survey Water-Supply Paper 2035, 68 p.

Wilson, J. M., 1965, Ground water resources and geology of Cumberland County, Tennessee: Tennessee Division of Water Resources, Water Resources Series 6, 56 p.

Zurawski, Ann, 1978, Summary appraisals of the Nation's ground-water resources - Tennessee region: U.S. Geological Survey Professional Paper 813-L, 35 p.

---- 1979, Hydrogeology of the Gatlinburg area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 79-1167, 79 p.

Zurawski, Ann and Burchett, C. R., 1980, Ground water in the carbonate rocks of the Franklin area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 80-410, 37 p.